# A Programmatic Plan for Restoration Action Effectiveness Monitoring and Research in the Lower Columbia River and Estuary

Prepared by G Johnson[1], C Corbett[2], M Schwartz[2], J Doumbia[3], J Sager[2], R Scranton[3], and C Studebaker[4]

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This document presents a plan for a programmatic approach to action effectiveness monitoring and research (AEMR[5]) that regional stakeholders can implement to support the Columbia Estuary Ecosystem Restoration Program (CEERP[6]) and the broader estuary restoration effort. The "actions" are habitat restoration projects in the lower Columbia River and estuary (LCRE). The objective of AEMR is to determine the success of restoration actions at site, landscape, and estuary-wide scales in terms of improved ecosystem functionality, especially as it relates to juvenile salmon performance. This work is being conducted within the CEERP's adaptive management framework (BPA/Corps 2012), within which restoration actions are implemented, AEMR is conducted, and results are analyzed, synthesized, and reported to decision-makers to evaluate, leading to adjustments in program strategy and subsequent restoration actions in the next cycle. AEMR is essential to the adaptive management process and the restoration effort.

Regional stakeholders, such as restoration project sponsors, can use this programmatic approach to provide context for their project-specific AEMR efforts. Stakeholder goals involve using AEMR to determine if their restoration actions were successful in meeting the project's objectives, identify improvements to restoration design and execution, and recognize efficiencies in AEMR efforts. These project-level goals match with similar goals at the CEERP program level, where interest lies in the collective success of multiple restoration projects synthesized across landscapes, the suite of improvements to restoration design and execution, and overall efficiencies in AEMR. This latter point is the focus of this programmatic AEMR plan.

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[1] Pacific Northwest National Laboratory (PNNL)

[2] Lower Columbia Estuary Partnership (EP)

[3] Bonneville Power Administration (BPA)

[4] U.S. Army Corps of Engineers, Portland District (Corps)

[5] Action-effectiveness *monitoring* involves spatially extensive sampling of basic restoration indicators, whereas action-effectiveness *research* involves locally intensive sampling at restoration and reference sites to characterize ecosystem structures, processes, and functions.

[6] CEERP is an acronym coined in 2011 for the joint BPA/Corps efforts to restore LCRE ecosystems that started with the 2000 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) (NMFS 2000) and now is responsive to subsequent FCRPS BiOps, the Council's Fish and Wildlife Program, and various Corps restoration authorities.

Programmatic AEMR guidance will be incorporated into technical proposals during the Estuary/Lower Columbia River categorical review within the Northwest Power and Conservation Council's Fish and Wildlife Program in fall 2012. Overall, the programmatic approach to estuary AEMR is being coordinated with the broader estuary restoration effort through the Lower Columbia Estuary Partnership, as well as the Columbia River tributary habitat AEMR and the federal research, monitoring, and evaluation (RME) effort under the 2008/2010 Federal Columbia River Power System Biological Opinion (NMFS 2008, 2010).

Herein we summarize key previous work on AEMR planning; explain a technical approach; prioritize AEMR activities, including what, when, where, and how much to monitor or research; and, define programmatic infrastructure, including projects, data management, reporting, communications, and leadership. The document closes with action items and a conclusion statement, a glossary, and references.

# Background

In this section, we describe previous AEMR planning efforts, identify common restoration actions, and summarize the state-of-science for AEMR, including important uncertainties in our understanding of the effectiveness of restoration actions in the LCRE.

## *Previous AEMR Planning*

Previous work on programmatic AEMR by the BPA/Corps is built upon for this programmatic AEMR plan. Three sources are particularly pertinent: Johnson et al. (2008), Roegner et al. (2009), and Johnson et al. (2012).

A basin-wide, federal BiOp RME effort commenced in 2000 (NMFS 2000). For the LCRE component of this effort, Johnson et al. (2008) produced a RME plan called the *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program*. This plan developed specific AEMR objectives that were incorporated into the 2008 FCRPS BiOp. At a programmatic level, AEMR was designed to use quantitative studies to demonstrate how habitat restoration actions affect factors controlling ecosystem structures and processes at site and landscape scales and, in turn, juvenile salmonid performance. The plan asserted that data sets developed through status and trends monitoring, implementation and compliance monitoring, critical uncertainties research, and AEMR would need to be established, maintained, analyzed, synthesized, and evaluated at a programmatic level. Data collection methods for action effectiveness, as well as the spatial and temporal scale of monitoring and example protocols, were also recommended, and are carried over in this current programmatic AEMR plan. As an outgrowth of the RME plan, BPA and the EP instituted an intensive AEMR effort at four sites in the LCRE and developed the suite of reference sites.

Standard data collection methods are critical to any programmatic approach to AEMR to ensure the data can be compared and integrated across locations and times. In the LCRE, Roegner et al. (2009a) published *Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary*, including "core metrics," "higher-order" indicators, and sampling designs for AEMR of habitat restoration projects. Categories of methods included hydrology, water quality, landscape, vegetation, and juvenile salmonids. Before -after-reference-impact and "accident response" designs for the purpose of AEMR were described. These protocols and sampling designs are currently being used regionally in project-specific AEMR. The Roegner protocols are available under the "methods" category at https://monitoringmethods.org/.

Johnson et al. (2012b), *Statistical and Other Considerations for Restoration Action-Effectiveness Monitoring and Research*, presented program- and project-level considerations for AEMR. These authors established a methodology for specifying statistical relationships between intensive action effectiveness research and extensive action effectiveness monitoring, including a method to indicate how much AEMR sampling is enough. They also provided a statistical approach for quantitative meta-analysis of AEMR data and offered approaches to prioritizing AEMR and critical uncertainties research. For reporting and documentation, they developed templates for project descriptions, AEMR plans, and site evaluation cards. Below, we apply these program- and project-level considerations for AEMR.

## *Restoration Actions*

AEMR depends on the attendant restoration actions. LCRE restoration actions involve improving or creating habitat for juvenile salmon in migratory and rearing areas and reconnecting floodplain habitats to the main-stem river (**Table 1**). To show coordination and communication with RME efforts elsewhere in the Columbia basin, a cross-walk between the LCRE and Columbia River tributary restoration actions reveals mostly commonality between the two areas. The few differences stem from structures and actions that are common in the LCRE, but not the tributaries; e.g., dredged channel material and pile structures. In both areas, actions are undertaken to acquire and protect land, restore riparian habitats, reconnect and restore off-channel and floodplain habitats, and control invasive plant species.

**Table 1**. Restoration Actions for LCRE and Comparable F&WP Tributary Restoration Action Categories. LCRE restoration actions and CRE# are from the Estuary Module (NMFS 2011). Restoration priorities from Roni et al. (2002) are used below in the section on Prioritization and Implementation.

| LCRE Restoration Actions | CRE# | Comparable F&WP Tributary Restoration Actions | Restoration Priority |
|---|---|---|---|
| Acquisition and protection | 1.3, 9.3 | Land acquisition or protection | 5 |
| Restore riparian areas | 1.4 | Riparian habitat (see invasive plants below) | 2 |
| Create habitat by applying dredged material to beneficial use | 6.2, 6.3 | Not applicable | 4 |
| Remove or modify pilings | 8.2 | Not applicable | 4 |
| Restore degraded off-channel habitat | 9.4 | Reconnection or creation of side-channels, ponds, wetlands and other off-channel habitats. Addition of habitat complexity (LWD) and cover to off-channel habitats | 5 |
| Breach dikes | 10.1 | Floodplain enhancement/reconnection | 5 |
| Remove tide gates or culverts | 10.2 | Barrier improvements | 5 |
| Upgrade tide gates or culverts | 10.3 | Barrier improvements | 1 |
| Control invasive plants and plant native species | 15.3 | Plant and plant removal | 2 |

From Roni et al. 2002, in order of priority:

- Tier 1- Actions which are synonymous with protection (regulations, conservation easement).
- Tier 2- Actions which deal with restoring habitat connectivity (could be regulation based or habitat improvement based).
- Tier 3- Restoring long-term process-water quality/quantity (roads, stormwater, instream flow, ect).
- Tier 4- Restoring long term processes-riparian.
- Tier 5- Restoring short term processes (enhancement projects).

### *State-of-Science*

The draft 2012 CEERP Synthesis Memorandum (Thom et al. 2012a) reviewed all available reports, peer-reviewed articles, and other communications concerning AEMR that included fish sampling for restoration actions in the LCRE over the past eight years. They found that AEMR has occurred throughout most of the LCRE, although emphasis was on the lower 90 km (**Figure 1**) where a majority of the restoration projects took place. Of the 56 restoration studies reviewed, only nine included fish sampling related to habitat opportunity, capacity, and realized function (Simenstad and Cordell 2002). Of these nine studies, only one (Crims Island; Haskell and Tiffan 2011) completed a statistical analysis of before-after restoration impact-reference data. In general, Thom et al. (2012a) concluded that hydrologic reconnections generally seem to improve access to shallow water habitats for juvenile salmon, but the degree of access depends on the degree to hydrologic reconnection. They noted that few studies examined effects on realized function for salmon, such as growth rate. These authors recommended that, where appropriate, AEMR include formal statistical study designs, reference and/or control sites, pre-restoration data collection, careful choice of monitored indicators, sampling year-round, site evaluation cards, and a central LCRE database. We heed these recommendations in this programmatic AEMR plan.

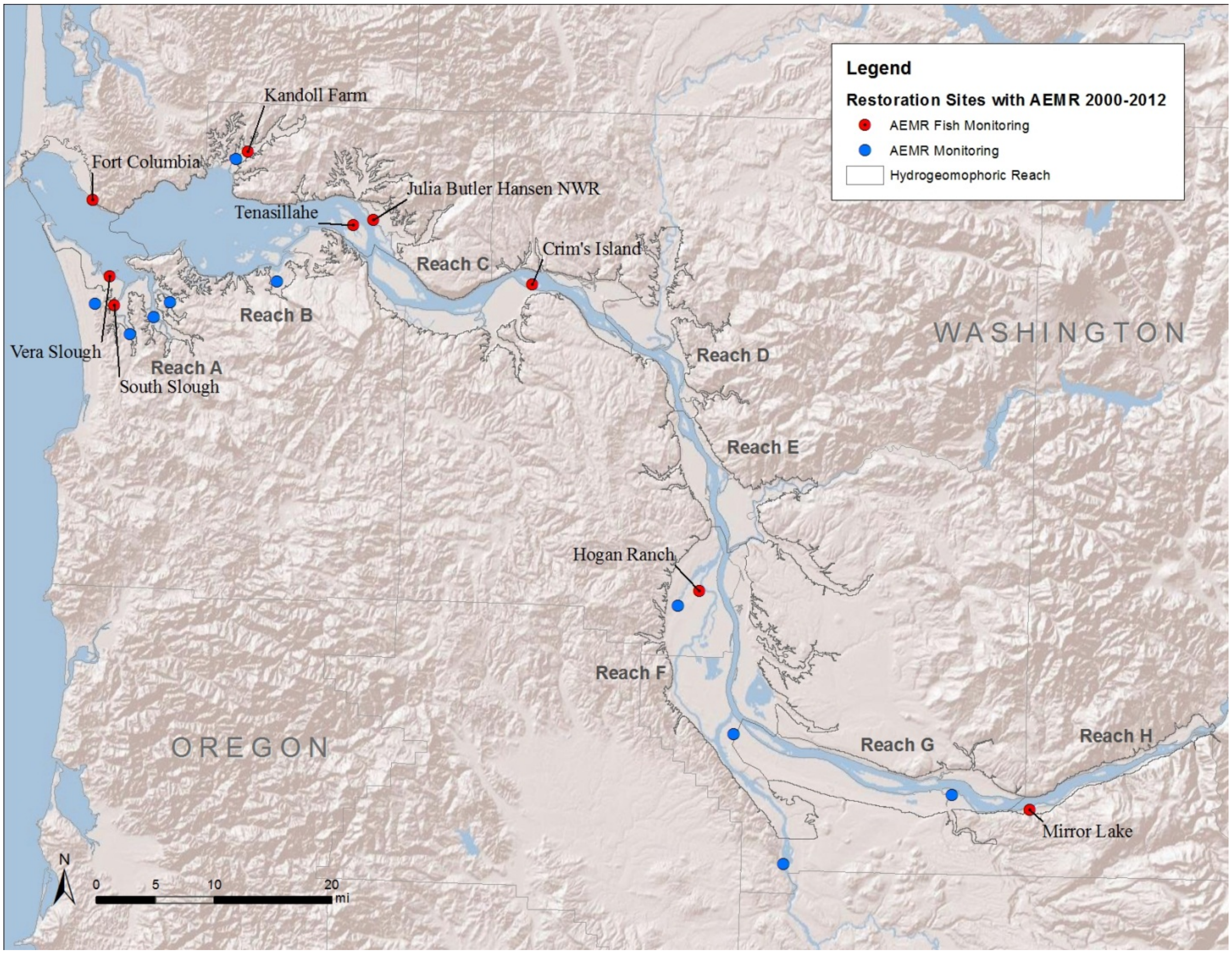


**Figure 1**. Map of Restoration Project Sites Where Pre- and Post-Construction AEMR Occurred During 2000-2012. Sites where fish were sampled and were included in the 2012 Synthesis Memorandum (Thom et al. 2012) are designated.

The state-of-science for AEMR has uncertainties. The Expert Regional Technical Group (ERTG) recently identified some from the point of view of scoring restoration projects to assign survival benefit units[7]. These are the high-level uncertainties; the ERTG provided more detailed sub-questions. Uncertainties will be considered in the Prioritization and Implementation section below.

- "What is the ecological role of LWD in tidal marshes, river floodplains, and floodplain lakes and ponds in the LCRE?"
- "What is the ecological role and impact of pilings on salmon?"
- "How do tidal wetlands respond to different types of restoration actions?"
- "What is the role of LCRE floodplain lakes/ponds relative to juvenile salmon?"
- "What is the role of seasonal floodplains in the upper estuary for juvenile salmon during floods?"
- "What are the functions of riparian vegetation for juvenile salmon along channel margins?"

[7] Draft memorandum from the ERTG to the Steering Committee, June 1, 2012.

- "Does the spatial organization of restoration projects have non-linear effects (e.g., amounts, synergies, thresholds, cumulative effects) on salmon use, survival, production, and life history diversity for stocks using those areas?"
- "How do hatchery-produced stocks affect the benefit of estuary restoration projects to natural stocks?
- "What is the stock-specific residency and use of various reaches of the estuary?"
- "What ecological measurements best estimate SBU's [survival benefit units] for various restoration actions?"

### *Summary*

This programmatic AEMR plan builds on a foundation of existing AEMR planning work, AEMR data collection protocols, statistical designs and analysis methods, a suite of restoration actions, and a frank assessment and synthesis of the state-of-science for AEMR in the LCRE. The technical approach that follows uses this foundation to refine and specify monitored indicators, sampling designs, and AEMR scales.

## Technical Approach

The technical approach for programmatic AEMR involves AEMR levels, standard extensive monitored indicators, extensive and intensive monitored indicators for ratio estimators, reference and control sites, and sampling design. This material is all site-scale,[8] but we also describe AEMR at landscape[9] and estuary-wide[10] scales.

There are many potential monitored indicators,[11] depending on program needs and project-specific conditions, ranging over a spectrum from extensive monitoring to intensive research (**Figure 2**). Any monitored indicator must be diagnostic of relevant ecosystem controlling factors, structures, processes, or functions, e.g., elevation, tidal exchange, water temperature, material flux (Thom and Wellman 1996); applicable to all sites with measurements that result in comparable data sets relevant to present and future investigations (Tegler et al. 2001); and practical in terms of funding, manpower, and processing and analysis requirements (Callaway et al. 2001). Rice et al. (2005), Thom and Wellman (1996), and Zedler (2001) present fundamental elements of monitoring aquatic habitat restoration projects.

[8] Site scale is the footprint of a given restoration project site (approx. 10s to 100s of meters).
[9] Landscape scale is an expanse of the LCRE (approx. 100s of meters to 10s of kilometers).
[10] Estuary-wide scale is from Bonneville Dam to the mouth of the river (235 km).
[11] A monitored indicator is a measurable parameter that is diagnostic of relevant ecosystem features, applicable and comparable across time and space, and practical to implement.

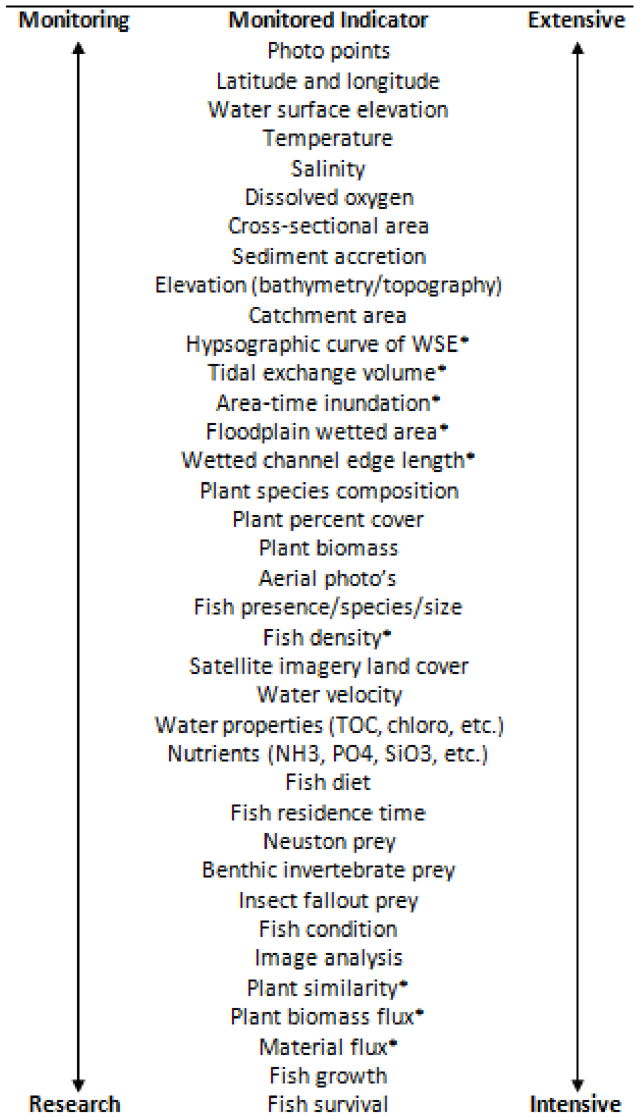


**Figure 2**. Monitored Indicators for Action Effectiveness Over the Monitoring/Research and Extensive/Intensive Spectrum (modified from Johnson et al. 2012). *Signifies a derived indicator, i.e., one calculator using data from another indicator.

### *AEMR Levels*

Implicit in the development of the programmatic AEMR plan is the spectrum of extensive monitoring to intensive research (Figure 2). We designate AEMR levels (

**Table 2** and **Figure 3**) to facilitate communication and prioritization of AEMR activities. Actual AEMR will depend on project and program needs and will likely be a blend of levels.

**Table 2**. AEMR Levels

| Designation | Name | Funding Source | Monitored Indicators | Intensity | Statistical Design | Term/Sampling Episodes[12] |
|---|---|---|---|---|---|---|
| Level 1 | Intensive | BPA/Corps | Intensive suite of monitored indicators of ecosystem structures, processes, and functions | Subset of sites | Essential | Long-term; 1-3, 6, and 10 y |
| Level 2 | Core | BPA/Corps | Extensive monitored indicators (core metrics of Roegner et al. 2009) | Subset of sites | Depends on project and program objectives | Medium-term; 1, 3, and 5 y |
| Level 3 | Standard | BPA/Corps or Sponsor | Standard extensive monitored indicators | All sites | n/a (qualitative assessment) | Short-term; 1, 5 y |

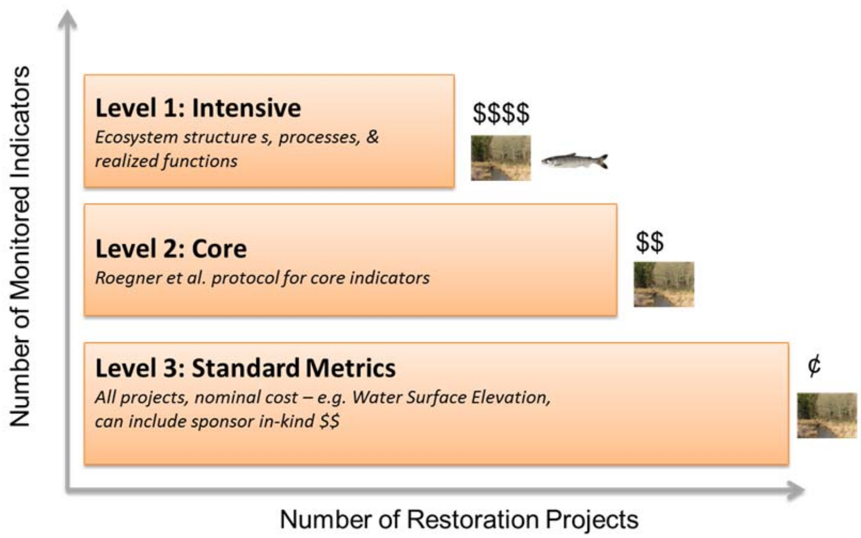


**Figure 3**. Schematic of AEMR Levels

### *Standard Extensive Monitored Indicators*

Data on a subset of standard, extensive monitored indicators (

Table **3**), dependent on the type of restoration strategy, should be collected at all project sites unless otherwise noted. These data will serve to document key environmental conditions at the site and suggest whether the restoration action is having the desired effect. This standard subset of monitored indicators

[12] Different indicators may have different frequencies.

does not include fish because the intent is to monitor the base physical environment, and minimize impacts on fish populations. As the AEMR database grows, we expect standard monitored indicators will suffice to determine the success of a project in terms of the physical changes realized and in the context of established relationships between extensive and intensive indicators. It is simply not practical for fish data, while very important at chosen priority sites, to be mandatory for all restoration projects. Also, the standard indicators do not cover all "core metrics" from Roegner et al. (2009a), thereby reducing costs and complexity while maintaining data usefulness for action effectiveness assessments. The standard indicators may also be used in intensive to extensive ratio estimators, as explained below, although again this is not mandatory.

**Table 3.** Standard Monitored Indicators by Restoration Action. These are Level 3 monitored indicators (

**Table 2**). Levels 1 and 2 are more intensive and will depend on project objectives.

| Monitored Indicator | Data |
|---|---|
| Photo Points | Discrete |
| Latitude and longitude | Discrete |
| Water-surface elevation | Logger |
| Temperature | Logger |
| Sediment accretion | Measurement |
| Elevation (topography) | Existing remote sensing dataset |
| Wetted area | Derived |

## *Extensive and Intensive Monitored Indicators for Ratio Estimators*

Relationships between extensive and intensive indicators are being established (Thom et al. 2012b) so that future studies can use measurements of extensive indicators in ratio estimators to predict the responses of related intensive indicators. By developing a proper mix of extensively monitored sites and intensively monitored sites, individual restoration projects may be surveyed with minimal effort while providing maximum opportunities to detect benefits at landscape and estuary-wide scales.

**Table 4**. Preliminary Data for Relationships Between "Extensive" (X) Monitored Indicator(s) and "Intensive" (Y) Monitored Indicator(s) (modified from Johnson et al. 2012); Use X to predict Y. These relationships remain to be fully quantified in the form of ratio estimators to provide statistically valid relationships. *Cross-sectional area is actually an extensive indicator; the relationship with catchment area what is important.

| "Extensive" Indicator(s) (X) | "Intensive" Indicator(s) (Y) | Reference |
|---|---|---|
| Water-surface elevation + land elevation | Floodplain wetted area; area-time inundation | Coleman et al. (2010) |

| | | |
|---|---|---|
| Water temperature | Juvenile salmon presence | Roegner et al. (2010) |
| Land elevation + lateral and longitudinal location in floodplain + sediment accretion rate | Plant community composition | Thom et al. (2012b) |
| Catchment area | Channel cross-sectional area at outlet*; wetted-channel edge length | Diefenderfer and Montgomery (2008) |
| Wetland area | Plant biomass export | Thom et al. (2012b) |
| Tidal exchange volume | Material flux (chlorophyll, dissolved organic matter, nutrients, plant biomass, macro-invertebrates) | Woodruff et al. (2012) |

Johnson et al. (2012b) established a methodology based on ratio estimation for specifying statistical relationships between intensive action-effectiveness research and extensive action-effectiveness monitoring. Extensive/intensive ratio estimators and predictive relationships are under development for several monitored indicators in the LCRE (Table 4). These relationships, which are being enhanced as new data become available, should be examined during design of new AEMR studies. Given extensive (easy) and intensive (difficult) indicators to sample (X and Y, respectively), the general ratio estimator is of the form (variances of the estimates may be included at a later date):

$$\hat{Y}_{ext} = X_{ext}\left(\frac{\bar{Y}_{\text{int}}}{\bar{X}_{\text{int}}}\right)$$

where $\hat{Y}_{ext}$ = estimated Y at an extensively monitored site

$X_{ext}$ = measured X at the same extensively monitored site

$\bar{Y}_{\text{int}}$ = mean of Y measured at multiple intensively researched sites

$\bar{X}_{\text{int}}$ = mean of X measured at multiple intensively researched sites.

### *Reference and Control Sites*

Reference and control sites are essential to AEMR studies where the objective is to determine the success or ecological benefits of a particular restoration action. A reference site is similar to the intended eventual outcome at the affected site after restoration, whereas a control site is similar to the affected site before restoration. Using control sites paired with each impact site can add additional statistical power to the analysis when looking to isolate changes in the restoration action compared to changes caused by natural variation or other sources. The use of reference or control sites or both in the sampling design (see next section) will depend on project and CEERP objectives.

AEMR science will benefit from the Lower Columbia Estuary Partnership's Reference Site Study, conducted from 2007 through 2012 (Borde et al. 2011, 2012). This study established a suite of 51 reference sites at relatively undisturbed wetlands for use as appropriate in AEMR work (Figure 4). Borde et al. (2011) provided detailed characterizations of the plant communities, water-surface elevations, water temperatures, and other features. Borde et al. (2012) analyzed these data to address two questions: 1) "What are the ranges of selected environmental factors controlling the establishment and distribution of wetlands in the LCRE, and what vegetation communities are associated with these ranges in different parts of the LCRE?" 2) "Can structural data from multiple reference sites be used to evaluate restoration action effectiveness in the LCRE and if so, what metrics are most useful to this evaluation?" The reference sites provide existing data to use in AEMR comparisons and analyses at site, landscape, and estuary-wide scales.

### *Sampling Design*

Sampling design includes frequency of AEMR sampling and formal statistical designs to evaluate the effects of restoration actions. Johnson et al. (2008) recommend sampling frequencies for many of the monitored indicators in

**Table 2** and Figure 3. Standard monitoring for action effectiveness will entail deployment of equipment for continuous data logging (e.g., water surface elevation and temperature), periodic (once per year for 5-10 y) measurements of sediment accretion and plant composition and percent cover, and photo points and aerial photographs.

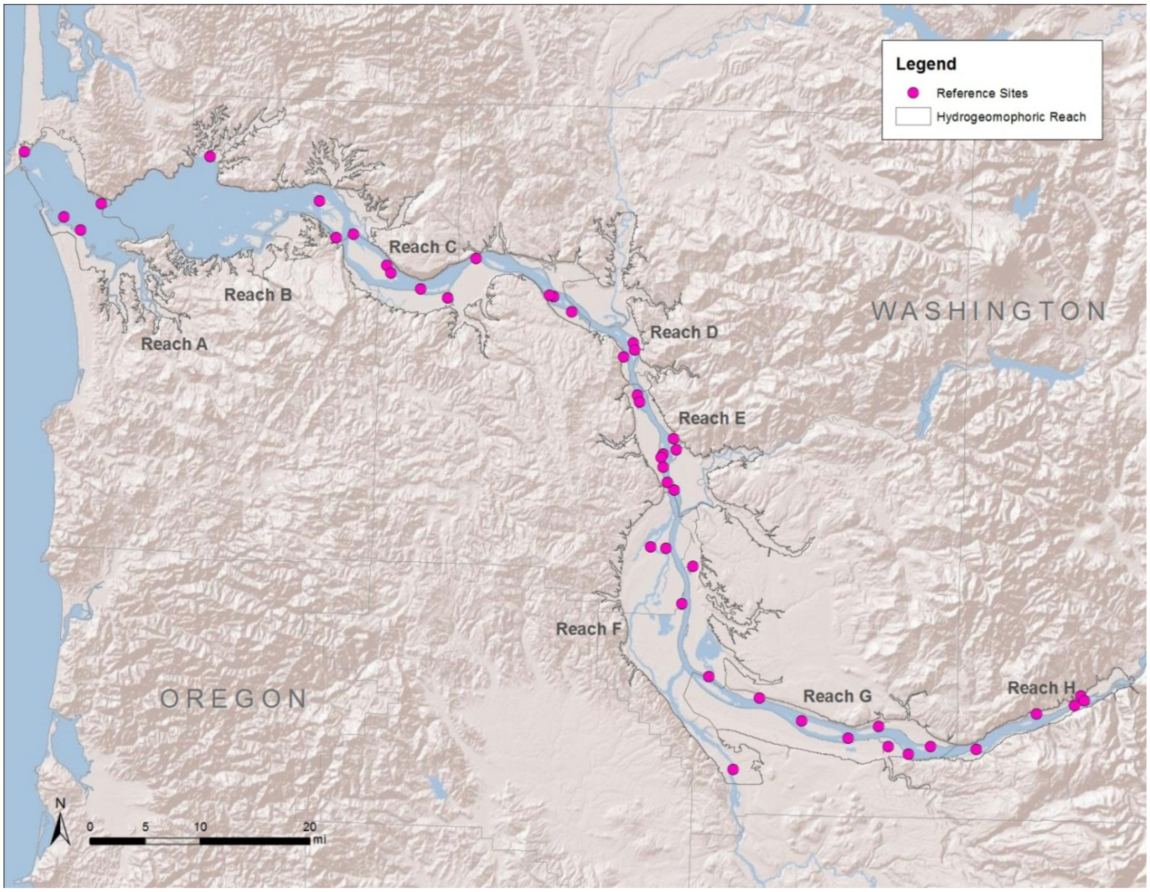


**Figure 4**. Map of Reference Sites

For more intensive AEMR studies, Johnson et al. (2008) and Roegner et al. (2009) presented designs based on sampling before and after restoration or after restoration only, with both designs involving a comparison of the affected site to an adjacent reference site. Documentation of conditions before a restoration action is warranted to show changes compared to after restoration; however, "before" sampling should be carefully considered because in many cases the restoration causes a profound and obvious change, e.g., breaching a dike to convert a pasture to a wetland. The reference site is essential to designs for intensive AEMR because it allows for analysis of the ecological trajectory of the restoration site. The idea is to assess whether the restoration action produced the desired shift in ecosystem structures, processes, and functions from state A to desired state B. Auxiliary questions could include how rapidly the shift occurred and the relative costs of alternative restoration activities. The sampling designs provided by Roegner et al. (2009) are appropriate for testing these questions in the complex environment of the LCRE. All intensive AEMR studies should be informed by a formal statistical design developed during the study planning stage and customized to meet the project's objectives and monitored indicators, i.e., identify and document reference/control sites, monitored indicators, and analysis methods ahead of time. Recommended sampling episodes for intensive AEMR are 1, 5, and 10 y after restoration, although timing for actual sampling may deviate from these recommended time steps depending on project and CEERP priorities.

How much AEMR sampling is enough is a common programmatic refrain. With regard to the number of intensively monitored sites, the intent is to select only a sample of the total restoration sites for such effort, say, $n$ of $N$ sites. At these sites, as mentioned above, higher-level ecological responses (i.e., intensive monitored indicators) would be measured along with correlated standard extensive indicators. Then using the standard or extensive data at all or most sites, an estimate of estuary-wide, total higher-level ecological response would be estimated by either ratio or regression estimation (Cochran 1977:150–203). Using the variance formula for regression estimators, the number of intensive monitoring sites that should be sampled can be calculated. The following material is from Johnson et al. (2012) and was prepared by Dr. J.R. Skalski.

Let $\hat{Y}$ represent the estimate of the estuary-wide, total response and $Y$ be the true value. Furthermore, define precision as

$$P\left(\left|\frac{\hat{Y}-Y}{Y}\right| < \varepsilon\right) = 1-\alpha$$

where the desire is for the relative error in estimation $\left(\text{i.e.,}\left(\frac{\hat{Y}-Y}{Y}\right)\right)$ to be less than $\varepsilon$, $(1-\alpha)$ 100% of the time. For example, if you wish to be within $\pm 25\%$ of the true value 90% of the time, then

$$P\left(\left|\frac{\hat{Y}-Y}{Y}\right| < 0.25\right) = 0.90 .$$

Using the above definition of sampling precision, then

$$\varepsilon \approx Z_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{\operatorname{Var}(\hat{Y})}}{Y}$$

and in the case of regression estimation (Cochran 1977:192)

$$\varepsilon \approx Z_{1-\frac{\alpha}{2}} \sqrt{\frac{\left(1-\frac{n}{N}\right)\mathrm{CV}_{Y_i}^2\left(1-\rho^2\right)}{n}}.$$

Solving for $n$ for given precision defined by $\varepsilon$ and $\alpha$

$$n = \frac{1}{\frac{\varepsilon^2}{Z_{1-\frac{\alpha}{2}}^2 CV_{Y_i}^2 (1-\rho^2)} + \frac{1}{N}}$$

where $\varepsilon$ = relative error size

$Z_{1-\frac{\alpha}{2}}$ = $Z$-value for a standard normal distribution at cumulative probability of $1-\frac{\alpha}{2}$

$N$ = total number of potential restoration sites

$\rho$ = correlation between intensive and extensive indicators

$\mathrm{CV}_{Y_i}$ = coefficient of variation in the intensive indicator response between restoration areas, i.e., $= \frac{\sqrt{\mathrm{Var}(Y_i)}}{\bar{Y}}$.

Consequently, the number of intensively monitored restoration sites $(n)$ will be a function of the desired level of precision (i.e., $\varepsilon$ and $1-\alpha$); how correlated are the intensive and extensive responses (i.e., $\rho$) and how variable are the restoration sites (i.e., $CV_{Y_i}$) Robson and Regier (1964) recommended for rough management purposes precision should be ±50%, 95% of the time (i.e., $\varepsilon$ = 0.50, $1-\alpha$ = 0.95) and for accurate management, ±25%, 95% of the time (i.e., $\varepsilon = 0.25, 1-\alpha = 0.95$. Using this framework, investigators should use preliminary data to estimate $\rho$ and CV for important higher-level responses and work with management to select useful levels of $\varepsilon$ and $1-\alpha$ all parties can agree upon.

### *Monitoring and Research Methods*

The standard monitoring and research methods developed by Roegner et al. (2009) are an important component of the programmatic AEMR because they will provide a means to analyze data across space and time. The methods by Roegner et al. (2009) cover the core indicators (Level 2;

**Table 2**) and are available at www.monitoringmethods.org:

- Hydrology: water-surface elevation, catchment area, tidal exchange volume, wetland delineation
- Water Quality: temperature, salinity, dissolved oxygen

- Topography/Bathymetry: elevation, sediment accretion rate, channel cross-sectional area
- Landscape: photo points, aerial photos
- Vegetation: percent cover, species composition, species richness, similarity index
- Fish: presence, abundance, species composition, size structure.

Johnson et al. (2008; Appendix C) provide information for methods for other more intensive indicators. Material for each monitored indicator includes a description, the data collection method, and reference(s) for an example protocol.

Project sponsors and AEMR practitioners will work together to identify the most appropriate methods given the specific monitored indicators and priorities for particular restoration project and programmatic objectives. Every effort will be made to employ standard methodologies to facilitate synthesis and evaluation at the program-level.

### *Landscape and Estuary-Wide Scales*

AEMR is necessarily conducted at the site scale, as discussed in this section, but the landscape and estuary-wide scales are also important to consider. There are ecological gradients longitudinally, laterally, and vertically in the LCRE that manifest themselves at the landscape and estuary-wide scales. For example, the influence of tides on water-surface elevation decreases as longitudinal distance upstream increases, while the opposite is true for Columbia River discharge (Jay et al. 2012). At a given longitudinal position, plant communities vary laterally as distance from the main stem and land elevation increase (Borde et al. 2011). This multi-dimensional variation in physical and biological features is evident in the LCRE Ecosystem Classification (Simenstad et al. 2011). Location of a restoration site in the landscape and estuary as a whole will affect ecosystem processes and functions at the site and, hence, the restoration design and associated AEMR at the site, landscape, and estuary-wide scales.

Ecosystem restoration strategy in the LCRE is based on a landscape perspective, as recommended by the Independent Scientific Advisory Board (ISAB 2011). As noted by the National Research Council (NRC 1992), the rates and patterns of the recovery of the wetland after hydrological reconnection vary considerably and are likely tied to the restored processes, which are highly dependent on the quality of the surrounding landscape. Therefore, it is appropriate that programmatic AEMR also have a corresponding landscape perspective. At the landscape scale, the working hypothesis is that “restoration actions in the LCRE will produce increased habitat connectivity and an increased area of floodplain wetlands trending toward historical levels present prior to land conversion for agriculture and the construction of dams” (Diefenderfer et al. 2011b). Monitored indicators such as aerial photography and satellite imagery are useful to characterize the landscape setting for a restoration site. Methodologies for landscape-level estimates of habitat connectivity (Diefenderfer et al. 2011a), life-history diversity (Diefenderfer et al. 2011a), and juvenile salmon density (Sather et al. 2012) have been developed and are ready for application to programmatic AEMR. Other methods are being developed to estimate restoration benefits to juvenile salmon at the landscape scale (Diefenderfer et al. 2011a). Many of these methods can be applied estuary-wide.

A technical approach for AEMR at the landscape or estuary-wide scale developed by Diefenderfer et al. (2011b) is based on levels-of-evidence (Downes et al. 2002). This approach uses analytical results from estuary-wide investigations of net ecosystem improvement (Thom et al. 2005), hydrodynamics (Diefenderfer et al. 2011b), ecological relationships (Thom et al. 2012b), and action effectiveness meta-analysis (Johnson et al. 2012), which are conducted using data from multiple sources, including a suite of reference and restoration sites across the LCRE (Diefenderfer et al. 2011b). The overarching working hypothesis is that "habitat restoration activities in the lower Columbia River and estuary have a cumulative beneficial effect on salmon" (Diefenderfer et al. 2011b). Several ongoing RME projects support analyses at the landscape and estuary-wide scales, e.g., Contributions to Recovery, Multi-Scale Action Effectiveness Research, Synthesis and Evaluation, and Ecosystem Monitoring (see section below on RME Projects). The emphasis currently is on site-scale AEMR, but work is already underway in the CEERP Synthesis Memorandum and the early stage Cumulative Effects Evaluation, among other efforts, to roll up AEMR data at landscape and estuary scales.

# Prioritization and Implementation

The AEMR data collection effort must be prioritized program-wide to make the best use of limited resources. This section of the programmatic plan provides a prioritization process that is used to establish AEMR priorities for the upcoming restoration actions. The RME projects designated to implement AEMR are described and activity matrices for implementation are presented.

## *Prioritization Process*

Criteria for AEMR prioritization (Table 5) are based on multiple sources. The presence of a suitable reference site is not one of the criteria for prioritization because it is too early in the process to be identifying reference sites. For Topic 1, Types of Restoration Actions, we applied "*A review of Stream Restoration Techniques and Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds*" by Roni et al. (2002) who offered five levels (decreasing order of priority): 5=Actions which are synonymous with protection; 4=Actions which deal with restoring habitat connectivity; 3=Restoring long-term process-water quality/quantity +habitat quality/quality; 2=Restoring long term processes-riparian; 1=Restoring short term processes (enhancement projects). We associated these priorities with the CEERP restoration actions (see Table 1). For Topic 2, Landscape location related to density of restoration, we divided the LCRE into three zones by combining reaches of the Columbia River Estuary Ecosystem Classification (Simenstad et al. 2011): upper zone (Reaches G-H); middle/transition zone (Reaches C-F); and lower zone (Reaches A-B). We examined the concentration of planned restoration actions from the "Get-After-It-List" (GAIL), a list of project identified by project sponsors in summer 2011. We then assigned scoring (3=much; 2=some; 1=little), depending on the density of planned projects in these 3 zones. For topic 3, Spatial gaps in previous AEMR work, we applied a similar approach by identifying the concentration of previous AEMR (Figure 1) and assigned scoring (3=little; 2=some; 1=much). Topic 2 may drop in importance over time if sufficient AEMR is undertaken for a given zone, while Topic 3 may gain in priority if spatial gaps continue. For Topic 4, Addresses a key uncertainty, we examined whether the AEMR project addresses uncertainties in the ERTG list (see above) or the recommendations of Thom et al. (2012) in the *CEERP 2012 Synthesis Memorandum*. These will be prioritized over the next year. For Topic 5, Survival Benefit Units (SBU), the assigned SBUs reflect the project's size, likelihood of ecological success, and anticipated benefits to fish access and habitat capacity (ERTG 2010b). The scoring measure is based on the average of the SBU values for ocean- and steam-type fish. The final topic, Scientific Implications for Implementation, is intended to inform future actions under CEERP.

The total score for a project is the sum over the 6 topics of the product of the scoring value and the weighting factor: minimum score = 11 and maximum = 36. The prioritization process should be applied periodically (~every 6 mon) by a prioritization committee made of up representatives from BPA, Corps, and EP that will be responsive to changing progress in the implementation of restoration actions and AEMR developments. The result of this process is a recommendation to the AA estuary program leads. The AAs will then consider timing and certainty of implementation in their final decision.

**Table 5.** AEMR Prioritization Framework. These are not the most important restoration actions; they are the important elements for RME.

| No. | Topic | Criterion | CEERP Priorities | Weighting Factor | Scoring Measures |
|---|---|---|---|---|---|
| 1 | Types of restoration actions | Actions strategically important to the restoration program | Hydrological reconnections; habitat creations | 2 | see Table 1 |
| 2 | Landscape location related to density of restoration actions | Locations in landscapes where restoration actions are concentrated | Results from GAIL (Get-After-It-List) | 1 | 3=much;<br>2=some;<br>1=little |
| 3 | Spatial gaps in AEMR | Location in landscapes where little AEMR has occurred | AEMR inventories | 1 | 3=little;<br>2=some;<br>1=much |
| 4 | Addresses a key uncertainty in action effectiveness | See list in the section above on State-of-Science | To be determined | 3 | 2=applies;<br>1=doesn't apply |
| 5 | Salmon survival benefit units | ERTG-assigned or preliminary SBUs (Note, ocean- and stream-type SBU assignments are summed) | Projects with high SBU values | 2 | 3= >3 SBU;<br>2= 1-3 SBU;<br>1= 0.3-0.99 SBU<br>0=<0.3 SBU |
| 6 | Scientific Implications for Implementation | Impact on CEERP implementation; timing of implementation. | Information has high potential to influence decisions | 3 | 3 = High<br>2 = Medium<br>1 = Low |

To determine the AEMR level, we developed a separate decision criteria. Actual AEMR levels (

**Table 2** and **Figure 3**) will depend on restoration project sponsor's goals and estuary-wide program needs. The criteria used to determine AEMR levels are based on the project sponsor's AEMR site plan and additional estuary spatial and statistical guidance questions. Initial consideration for AEMR levels is based either on an established AEMR plan for the restoration site or an AEMR template (Johnson et al 2012). These AEMR plans provide information to complete a monitoring matrix which summarizes the monitoring plans for all prioritized sites. Specifically, the monitoring matrix codifies AEMR plans and templates to address the following:

- limiting factors identified at the restoration site
- specific restoration actions implemented to address those limiting factors

- objectives for addressing the limiting factors through the restoration actions
- performance criteria of project implementer's definition of success
- metrics for evaluating the success of actions
- and whether a reference site or control sites has been identified and defines the intended statistical design (i.e., BACI or Accident response).

AEMR plans in a systematic format will make it easier to compare intended AEMR at restoration sites and also evaluate if AEMR plans have considered all appropriate monitoring metrics

To further guide AEMR level designation, we also will consider additional river and estuary-wide spatial and statistical questions (Table 6). Question 1 establishes if AEMR related to a specific action has occurred within a reach, with emphasis on monitoring actions in reaches that have had no previous AEMR. Question 2 captures within reach habitat variability, prioritizing the monitoring of restoration actions that have been monitored within a reach but not a specific habitat. Question 3 prioritizes sites that provide insight into increased capacity, opportunity, or realized function for juvenile salmonids. In order to strengthen the link between extensive and intensive monitoring, question 4 supports higher AEMR levels for sites that can provide data to inform intensive/extensive ratio estimators. Question 5 prioritizes sites based on level of precision required for a given restoration action, with emphasis on sites needed to meet the level of precision specified by Johnson et al. 2012. These guidance questions incorporate larger spatial and statistical questions in site level AEMR planning process and help inform which sites should be considered for more intensive monitoring. Based on project goals, estuary wide considerations, and available funding, Action Agencies and collaborating partners will then make the final determination on AEMR levels for restoration sites.

**Table 6:** Guidance questions used to assist in designation of AEMR Levels

| No. | Question |
|---|---|
| 1 | Has action (CRE subaction) been previously monitored in reach? |
| 2 | Has action (CRE subaction) been previously monitored in that habitat in that reach? |
| 3 | Does data provide insight into increased capacity, opportunity or realized function between habitats or CRE subactions |
| 4 | Is more data needed to generate ratio estimator related to action (CRE subaction)? |
| 5 | Does sufficient data exist to satisfy AEMR level of precision for a given action (CRE subaction)? |

### *AEMR Priorities*

The ongoing and upcoming restoration projects are listed to provide the universe of potential sites for AEMR (Table 7; Figure 5). We set AEMR prioritization levels for these projects using the criteria and priorities above (Table 5). Application of the prioritization process is scheduled for October 2012.

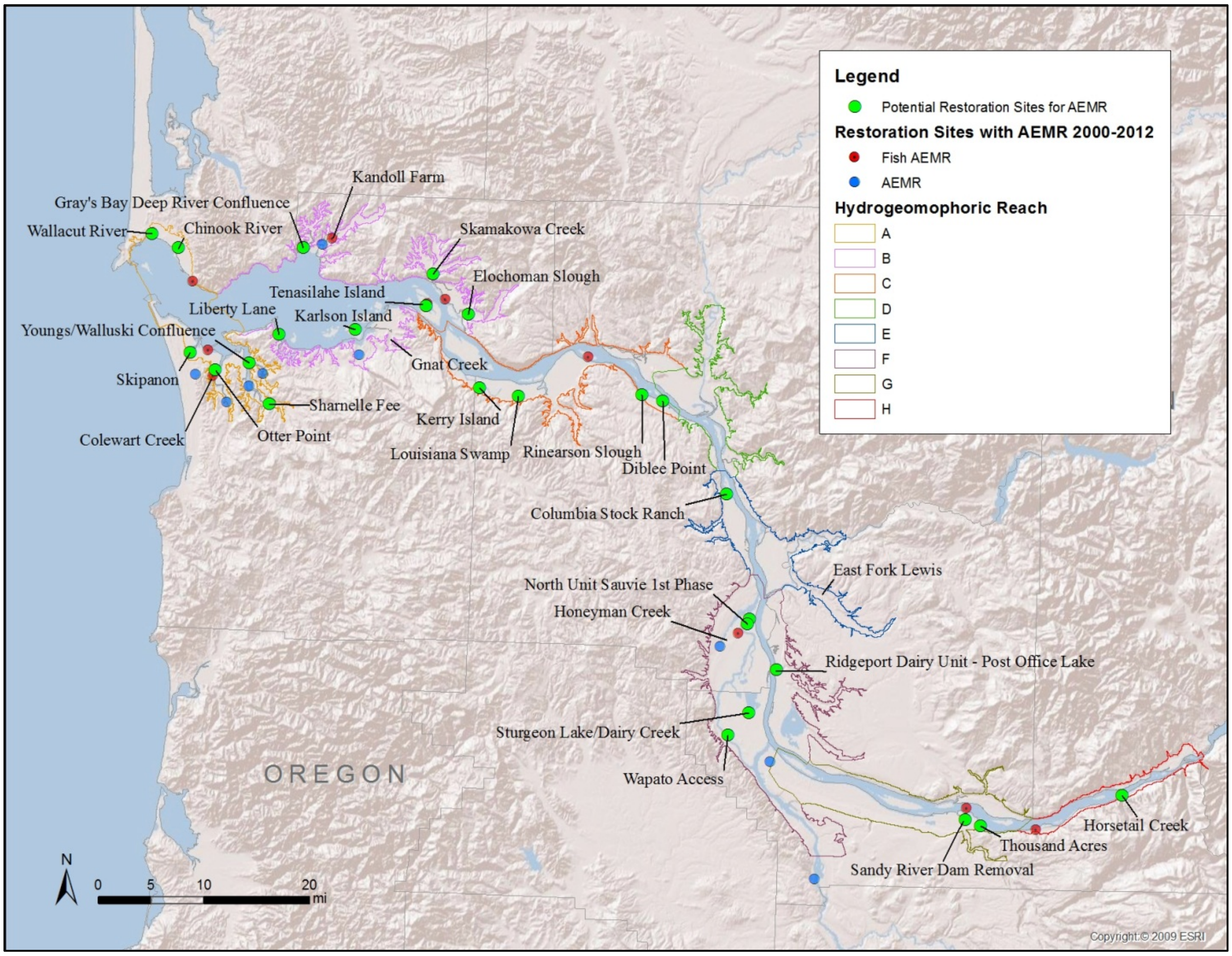


**Figure 5.** Map of Previous and Potential New AEMR Sites.

**Table 7.** Prioritization of AEMR Level (
Table **3**) for Ongoing and Upcoming 2012-2014 Restoration Projects. *These sites are located up tributaries, therefore the distance from the Columbia River mouth represents the distance to the mouth of the tributary, not the distance up the tributary. The AEMR level and priority score will be determined at a later date. This list does not imply a commitment to fund AEMR.

| Restoration Project | Rkm | Construction Year(s) | Type of Restoration Action | AEMR Level | Priority Score |
|---|---|---|---|---|---|
| Chinook | 8* | 2013 | Acquisition and tide gate modification | | |
| Colewort Creek | 19* | 2012 | Channel modification - off/side channel creation/ enhancement | | |
| Columbia Stock Ranch | 122 | 2013 | Hydrologic reconnection | | |
| Dairy Creek/Strugeon Lake | 159 | 2013 | Hydrologic reconnection | | |

| Restoration Project | Rkm | Construction Year(s) | Type of Restoration Action | AEMR Level | Priority Score |
|---|---|---|---|---|---|
| Dibblee Point | 103 | 2013 | Off/side channel creation/ enhancement | | |
| East Fork Lewis | 138* | 2014 | Culvert modification - woody debris placement | | |
| Elochoman | 60 | 2014 | Culvert replacement | | |
| Gnat Creek | 43* | 2012 | Hydrologic reconnection - dike breach/removal and dam removal | | |
| Grays Bay – Deep River Confluence | 21* | 2014 | Hydrologic reconnection – dike breach | | |
| Honeyman Creek | 140* | 2012 | Culvert removal | | |
| Horsetail Creek | 222* | 2013 | Culvert modification - woody debris placement | | |
| Karlson Island | 42 | 2013 | Hydrologic reconnection - dike breach | | |
| Kerry Island | 43 | 2014 | TBD | | |
| Louisiana Swamp | 77 | 2013 | Hydrologic reconnection - dike breach | | |
| Liberty Lane (Tongue Point) | 18 | 2012 | Tide gate modification | | |
| Otter Point | 19* | 2012 | Hydrologic reconnection - dike breach | | |
| Port of Astoria (Skipanon) | 10 | 2014 | TBD | | |
| Post Office Lake | 151 | 2013 | Hydrologic reconnection | | |
| Rinearson Slough | 100 | 2014 | Tide gate modification | | |
| Sandy River | 195 | 2012 | Dam removal | | |
| Sauvie Island, North Unit 1st Phase | 143 | 2013 | Hydrologic reconnection - remove water control structure | | |
| Sharnell Fee - Klaskanine River | 19* | 2013 | Hydrologic reconnection - dike breach | | |
| Skamokawa Creek – Dead Slough | 53* | 2012 | Culvert improvements | | |
| Thousand Acre | 200 | 2013 | Tide gate removal - off/side channel creation enhancement | | |
| Tenasillahe Island/ TK Slough | 56 | 2013 | Hydrologic reconnection | | |
| Wapato Access | 163 | 2013 | Off/side channel creation/enhancement | | |
| Youngs/Walluski Confluence – Restoration Phase | 12 | 2014 | TBD | | |

### *RME Projects*

AEMR will be implemented through ongoing and, as necessary, new RME projects. Ongoing 2012 AEMR activities include one project under the F&WP (BPA) and five projects under the Anadromous Fish Evaluation Program (Corps) processes. Most BPA/Corps RME activities for the LCRE were placed with the Corps as part of the Washington Memorandum of Agreement (Washington-Action Agencies 2009). The following AEMR projects are described further in the *2012 CEERP Action Plan* (BPA/Corps 2012). Of these, the Ecosystem Monitoring project and the Multi-Scale Action Effectiveness Research project are the main studies funded to perform AEMR in 2013.

- The Ecosystem Monitoring project (BPA 2003-007-00) is conducting AEMR at selected restoration projects. Four restoration sites have been intensively researched since 2008: Mirror Lake (off-channel and riparian improvements); Sandy River Delta (invasive plant control); Hogan’s Ranch (riparian improvements and invasive plant control); Fort Clatsop (hydrological reconnection). This research is ongoing in 2012, but resources may be reallocated for 2013.
- The Cumulative Effects project (Corps EST-P-02-04) is in the closeout phase, delivering its last annual report in April 2012 and producing a first-ever levels-of-evidence analysis in summer 2012.
- The Multi-Scale Action Effectiveness Research project (Corps EST-P-11-01) is conducting site-scale AEMR sampling at three sites (Sandy River delta [SRD], Julia Butler Hanson [JBH] National Wildlife Refuge, and Tenasillahe), fish density estimation to relate to restoration actions at the landscape scale (St. Helens to Longview), and preparing for eventual estuary-wide cumulative effects evaluations. At SRD, “before” sampling is underway for a proposed hydrologic reconnection. At JBH and Tenasillahe, tide gate replacements are being studied using before-after reference-impact and recovery model sampling designs.
- The Salmon Benefits project (Corps EST-P-09-01) is a methods-development study that is producing indices for habitat connectivity, early life-history diversity, and restoration benefits to juvenile salmon. The BPA/Corps intend to apply these indices to measure and track restoration action effectiveness at site, landscape, and estuary-wide scales.
- The Synthesis and Evaluation project (Corps EST-P-11-01) is developing a geospatial database for the LCRE that will eventually include AEMR data from multiple sites, projects, and researchers to disseminate data and enable comprehensive syntheses and evaluations of AEMR in the LCRE.

### *Activity Matrix*

The programmatic plans for AEMR data collection activities in the near-term and long-term are yet to be determined. A possible structure to convey this work is shown in the activity matrix in Table 7.

**Table 8.** 2013 AEMR Implementation – Activity Matrix

| Restoration Project | Status | AEMR Level | RME Project | Sampling Frequency | Out-Year Plan | Comment |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

## Programmatic Infrastructure

Effective and useful AEMR requires a programmatic infrastructure. This entails an adaptive management framework, coordination and peer-review processes, project-specific AEMR plans, standardized data collection and analysis, centralized data management, reporting and communications mechanisms, and leadership. Most importantly, there must be a commitment from all stakeholders to participate and cooperate in the conduct of AEMR and the overall adaptive management framework to produce AEMR results that are useful to program goals and objectives. To date, AEMR in the LCRE could have been better coordinated, prioritized, analyzed, and reported, shortfalls due in part to poor programmatic infrastructure.

### *Adaptive Management Framework*

AEMR is coordinated, prioritized, implemented, synthesized, and evaluated within the ongoing CEERP adaptive management framework (BPA/Corps 2012). AEMR, as a component of the overall RME effort in the adaptive management cycle, is critical to determining the success of restoration at site, landscape, and estuary-wide scales. The adaptive management framework provides a foundation for a programmatic infrastructure for AEMR. Other infrastructure elements, such as coordination and data management, are conducted within this adaptive management framework.

### *Coordination and Peer-Review Processes*

The Estuary Partnership convenes annual meetings to coordinate on-the-ground RME activities in the LCRE. This meeting in February or March each year focuses on communication among researchers and managers of upcoming field sampling dates and locations.

Coordination for AEMR also occurs through existing regional coordination efforts, such as the Corps' Anadromous Fish Evaluation Program (AFEP), the Council's Fish and Wildlife Program (FWP), and the Lower Columbia Estuary Partnership's (EP) programs. Within these programs, work groups contributing to coordination purposes include the federal Estuary/Ocean Subgroup for Federal RME, the AFEP Studies Review Work Group (SRWG), the EP's Science Work Group, and the Expert Regional Technical Group. Peer-review takes place during coordination meetings and reviews. For example, the SRWG provides peer-review of preliminary and final proposals and draft technical reports from the Corps' RME projects in the LCRE. Most importantly, a special AEMR planning prioritization committee with representatives from BPA, Corps, and EP will be established to coordinate the AEMR effort.

Other important peer-review is provided by the Independent Scientific Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP) of the Council's FWP. During summer 2012, the ISAB is scheduled to review the CEERP 2012 Synthesis Memorandum, which will contain AEMR results to date. And, during fall 2012, the ISRP is slated to review the BPA's LCRE habitat restoration projects, whose strategies and designs will be informed by AEMR findings.

### *Project-Specific AEMR Plans*

Every restoration project should have a written plan for AEMR. Such plans can range from a paragraph describing pre- and post-restoration site conditions coupled with photo points to an intensive research design to be carried out over 5 to 10 years. AEMR plans will be restoration project-specific, depending on local conditions, type of restoration, available funding and time, and other factors. Johnson et al. (2012) provide a template for project-specific AEMR plans consistent with the adaptive management process and the project description templates (ERTG 2010). The point is to document, coordinate, and obtain management review and approval of the plan for site-specific AEMR before field work commences.

### *Centralized Data Management*

AEMR is only as good as the data and information it produces. Currently, however, there is no centralized database for AEMR or other data in the LCRE. A geo-spatial database is needed to store past and future data, facilitate data sharing among research and restoration practitioners, and be used as the basis for synthesis and evaluation of LCRE data. This database should be developed in form and function to relate to other relevant regional data systems (e.g., StreamNet, CBFISH). The intent is to provide a publicly accessible, interactive map-centered interface to access LCRE AEMR and other data for comprehensive analyses. A new AFEP project (EST-P-12-01) commenced in 2012 to meet this need. The project's objectives are to: 1) coordinate with funding agencies and regional stakeholders to ensure the database system will meet management's needs for ecosystem restoration throughout the floodplain study area of the LCRE; 2) develop and populate a web-based, publicly-accessible geospatial database management and analysis system to support action planning, RME, synthesis and evaluation, strategy development, reporting, public communication, regional and basin review processes, information dissemination, and decision-making, i.e., adaptive management; and, 3) apply data and information within the adaptive management process. During 2012 and 2013, data reduction protocols, data access and sharing policies, and uploading procedures will be drafted for the LCRE database.

### *Reporting and Communication Mechanisms*

Site evaluation cards (SEC) have been designed (Johnson et al. 2012), and recently refined by the Estuary Partnership, so that information in the project template and the AEMR plan can be copied and pasted directly into the SEC document. SECs were first proposed by Thom et al. (2008) as a mechanism for systematically recording AEMR data from restoration projects. The intent was and still is to use the SECs to synthesize AEMR data in periodic meta-analyses. The SEC template was designed with the context that its utility and value depend on the ability and ease with which it can be accurately completed by a wide range of restoration personnel. If the SEC were too large, too demanding, or too complicated it would decrease the chances of its being completed. However, without the SEC, the ability to systematically capture AEMR data and use the data to respond to reporting requirements is diminished. SECs will be required for regular reporting by AEMR practitioners and will be archived in the LCRE Database.

RME projects conducting AEMR produce progress reports, technical memoranda, annual reports, and SECs. These reporting documents will be categorized and housed in an electronic library in the central LCRE Database. AEMR practitioners will strive to provide timely reporting of findings to facilitate synthesis and evaluation.

The Synthesis Memorandum is one of three inter-related, annual CEERP deliverables; the others are the Strategy Report and Action Plan. The Synthesis Memorandum, which is informed by the SECs and various AEMR reports, synthesizes the state of the science on salmon ecology in the LCRE and what was learned from AEMR. It provides a scientific basis for the restoration strategies described in the Strategy Report, which in turn is used to implement restoration and RME actions outlined in the companion Action Plan. Further AEMR is conducted and the results are synthesized in the next Synthesis Memorandum. The Synthesis Memorandum provides one main report on AEMR results and their management applications that managers can use to make decisions.

The biennial Columbia River Estuary Conference (every even-numbered year) is a useful forum to report and communicate AEMR findings to a wide range of participants. Conference organizers encourage substantial exchange of new data and information among researchers, policy-makers, resource managers, and the public.

Communications that contextualize and summarize the management applications of AEMR findings are essential to foster program support among policy-makers and the public. For example, communication pieces from restoration program managers to a wider, non-technical audience might entail notices of key findings or accomplishments and what they mean to society.

### *Leadership*

All successful programs have people who are in charge and provide leadership. This presents a challenge for AEMR in the LCRE because restoration and RME are conducted by various entities under various authorities for various purposes. The programmatic AEMR plan herein addresses this challenge in a significant way, but without leadership it will likely not meet expectations. Therefore, we propose creation of an AEMR Leadership Team comprised of three members, one representative each from BPA, Corps, and Estuary Partnership. BPA and Corps, as the primary funding agencies, will alternate chairing the team. The Estuary Partnership, as a National Estuary Program body, will represent the views of regional partners to the team. It would be the team's responsibility to integrate the results of individual monitoring and research efforts, ensure that the data are analyzed from an estuary-wide perspective, disseminate the information, and evaluate the program. The team would also be tasked with ensuring that adaptive management is built into routine, cyclic program management. The first assignment for this team could be to review and approve this programmatic AEMR plan.

## Action Items and Conclusion

The following list summarizes action items from the programmatic AEMR plan.

- quantify the extensive/intensive monitored indicator relationships in the form of ratio estimators
- update and refine the Roegner protocols and develop a "wiki" for them
- develop data reduction protocols to accompany the Roegner protocols
- write restoration project-specific descriptions (ERTG 2010), AEMR plans, and site evaluation cards, and disseminate them via the LCRE Database
- develop and operationalize the LCRE Database in coordination and integration with other Columbia basin database efforts such as CBFISH.org
- establish an AEMR Leadership Team to lead implementation of AEMR within the existing CEERP adaptive management framework.

Action effectiveness is a critical element of the CEERP adaptive management process. It is important to monitor the effectiveness of restoration actions to know how well they are performing relative to their intended purpose. Funds for AEMR, however, are limited and need to be spent wisely to obtain useful, cost-effective information for management. The programmatic AEMR plan herein helps address this need.

## Glossary

***adaptive management* –** A structured learning process for testing hypotheses through management experiments in natural systems, collecting and interpreting new information, and making changes based on monitoring information to improve the management of ecosystems; i.e., "learning by doing."

***attribute* –** Frequently called "metric" or "parameter," this is the specific variable that is measured to assess the response of the system, e.g. "percent cover" or "survival."

***census* -** A complete and thorough collection of data on the population at hand.

***conceptual ecosystem model* –** A graphical representation or a simple set of diagrams that illustrate a set of relationships among factors important to the function of an ecosystem or its subsystems (Busch and Trexler 2003).

***connectivity* –** See “habitat connectivity.”

***controlling factors*** – The basic physical and chemical conditions that construct and influence the structure of the ecosystem.

***control site* –** Locations with traits similar to the subject site prior to restoration. These sites are sampled over time to monitor any temporal shifts in baseline conditions and how the subject area might have responded over time had no restoration taken place.

***core indicators* –** A standard subset of the suite of possible indicators that is usually measured at sample locations (Roegner et al. 2009). They must be relevant to the objective.

***ecosystem*** – A community of organisms in a given area together with their physical environment and its characteristic climate.

***ecosystem function* –** Ecosystem function is defined as the role the plant and animal species play in the ecosystem. It includes primary production, prey production, refuge, water storage, nutrient cycling, etc.

***ecosystem process* –** Ecosystem processes are any interaction among physicochemical and biological elements of an ecosystem that involve changes in character or state.

***ecosystem structure* –** Ecosystem structure is defined as the types, distribution, abundances, and physical attributes of the plant and animal species comprising the ecosystem.

***evolutionarily significant unit*** – A population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component in the evolutionary legacy of the species (Johnson et al. 1994). Seventeen ESUs have been designated and mapped in the Pacific salmon range in California, Washington, Oregon, and Idaho. Each unit generally includes a major river basin such as the Snake or Sacramento Rivers or a section of coastline that may include several river basins as in the California Central Coast ESU.

***extensive monitoring*** – monitoring of a few selected core indicators over a large spatial scale.

***habitat* –** The physical, biological, and chemical characteristics of a specific unit of the environment occupied by a specific plant or animal.

***habitat capacity* –** A category of habitat assessment metrics including "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics (cf. Simenstad and Cordell 2000).

***habitat connectivity* –** A measure of how connected or spatially continuous a corridor between habitats or among habitats in a matrix is.

***habitat opportunity* or access –** A category of habitat assessment metrics that "appraise the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features (cf. Simenstad and Cordell 2000).

***habitat usage* –** Measures of juvenile salmonid/habitat relationships in the estuary such as residence time, growth, and diet.

***indicator* –** A measurable parameter that characterizes an important aspect of the ecosystem and is sensitive to changes in the system.

***intensive monitoring*** – monitoring of many core and higher order indicators locally, i.e., over a small spatial scale.

***life history diversity*** – Different spatial and temporal patterns of migration, habitat use, spawning, and rearing displayed within a population of Pacific salmon.

***limiting factor* –** Physical, chemical, or biological features that impede species and their independent populations from reaching viability status.

***monitoring* –** The systematic process of sampling design, collection, storage, and analysis of data related to a particular system at specific locations and times (Busch and Trexler 2003).

***monitored indicator*–** See "indicator."

***ocean-type life history*** – General life history pattern for salmon in which juveniles migrate to sea during their first year after emergence.

***protocol* –** The standardized methodology to collect data for a monitoring indicator (Busch and Trexler 2003).

***realized function*** – A category of habitat assessment metrics that includes any direct measures of physiological or behavioral responses that can be attributable to fish occupation of the habitat and that promote fitness and survival; for example, survival, habitat-specific residence time, foraging success, and growth (cf. Simenstad and Cordell 2000).

***reference site* –** Locations considered to be representative of the desired outcome of the restoration action. Reference sites are used to characterize the spatial heterogeneity of the target condition and any temporal shift in the target condition over time due to climate change, maturation, etc. This differs from a "control" site which should be similar to the restored site before restoration.

***restoration*** -- Return of an ecosystem to a close approximation of its previously existing condition (NRC 1992).

***sample*** -- To collect data under a prescribed sampling design.

***stream-type life history*** – General life history pattern for salmon in which juveniles migrate to sea after one year of rearing in their natal stream system.

***stressor* –** An entity or process that is external to the estuary or anthropogenic and that affects controlling factors on estuarine ecosystem structures or processes. A component of a conceptual model.

***track*** -- To access, assess, and summarize information made available by others.

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