LOWER CLACKAMAS RIVER BASIN

MACROINVERTEBRATE MONITORING PLAN

Prepared for

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Clackamas River Water Providers (CRWP) is a coalition of municipal water providers that receives drinking water from the Clackamas River. CRWP receives water from the lower Clackamas River at 5 points of diversion (POD) at river miles 0.8, 1.7, 2.7, 3.1, and 22.7. CRWP is working to ensure that the river and its tributaries are monitored to adequately assess and protect water quality. Recognizing the utility of biological monitoring for assessing water quality, CRWP undertook the following study to develop and implement a long-term macroinvertebrate monitoring strategy for the lower Clackamas River Basin.

Macroinvertebrate assessments are routinely included in most comprehensive water quality assessments because macroinvertebrate communities are widely recognized as excellent indicators of water quality and physical habitat conditions (Karr and Chu 1997). Macroinvertebrate assemblages, by virtue of their diversity and attendant variation in tolerance to pollution and various other perturbations, integrate the effects of myriad physical and chemical stressors. These relationships have been well documented, and from these studies tools have been developed that allow determination of overall water quality conditions based on an examination of macroinvertebrate community composition. Among the many useful applications for bioassessment with macroinvertebrates is tracking long-term trends in overall water quality within a particular waterbody or geographic area.

The CRWP intends to utilize macroinvertebrate assessments, potentially including those performed in the past, to assist with informing water quality conditions in the lower Clackamas River and major tributaries. Past efforts may allow for comparison of past conditions with present and future conditions to allow for longer-term trending and identification of any potential changes that have occurred in general water quality conditions. The goal of the CRWP macroinvertebrate monitoring strategy is to track trends in water quality conditions using macroinvertebrates in the lower Clackamas River and tributaries entering the Clackamas River. Focus watersheds and subwatersheds to be included in the monitoring efforts include Rock, Richardson, Deep, Goose, Eagle, Clear, and Foster creeks. Specific monitoring objectives are as follows:

- Determine spatial variation and long-term temporal trends in macroinvertebrate community conditions within the mainstem Clackamas River from immediately below Mill River Dam downriver to the confluence with the Willamette River.
- Track long-term trends through regular monitoring of macroinvertebrate community conditions in each of the major tributaries entering the lower Clackamas River.

OVERALL APPROACH

In order the meet the stated objectives above, a comprehensive and consistent monitoring effort is required. Because macroinvertebrate assessment and, to a certain degree, monitoring have already been occurring in the lower Clackamas River basin, the CRWP wished this planning process to include a review of past and existing assessment efforts to determine the extent to which previous and existing efforts could serve to inform these objectives. With a characterization of the existing efforts relative to stated needs, the CRWP could objectively assess what additional sampling/data would be necessary to fully meet the plan objectives. As such, the overall approach to developing this monitoring plan consisted of the following steps:

1) Determine sampling design and data needs relative to stated objectives of the monitoring program: First, sampling design and data needs were identified to provide an objective context for examining the potential utility of existing data for inclusion in the long-term monitoring dataset. This first step included an identification of appropriate long-term monitoring stations in the lower Clackamas River basin.

2) Gather all existing data and determine extent of past, present, and planned efforts: Second, all known existing studies, their designs, technical elements, and their data were reviewed and evaluated relative to the needs identified in the first step of the planning process. To ensure an objective review of the data, review criteria were established for each design and technical element identified in the first step. Each study was reviewed using these criteria and only studies conforming to these criteria were considered in the gap analysis.

3) Identify gaps in existing efforts: Studies determined to be of sufficient technical rigor were summarized to identify overlap between these sampling locations and proposed long-term monitoring locations identified in step 1. With this information, additional data needs necessary to meet the stated monitoring objectives were determined.

4) Monitoring Plan: This final step presents a concise summary of the recommended monitoring strategy and elements required to meet the long-term monitoring objectives.

Each of these steps and the results thereof are treated in the following sections.

DESIGN AND DATA NEEDS EVALUATION

After identifying the long-term monitoring objectives, data required to meet these objectives were identified. In determining data needs, sampling design (arrangement and number of sites, as well as sampling frequency), sampling methods, laboratory methods (taxonomic effort), and appropriate data analyses were considered. Each of the following sections describes requisite elements and/or levels of rigor recommended for producing a long-term biomonitoring dataset for the lower Clackamas River basin.

SAMPLING DESIGN

Selecting an appropriate sampling design is critical to the success of any monitoring program. Both spatial and temporal aspects of the design must be suited to the study objectives. The method of site selection is an important aspect of any monitoring program, and the various methods can be broadly grouped into random and non-random approaches. A number of random (probabilistic) sampling designs have been developed, each with the intent to allow inferences to be made about unsampled elements/units of the resource of interest within the study area (Fancy et al. 2009). Only probablistic survey designs are statistically based and therefore provide unbiased population estimates.

Non-random designs can include representative/judgment, systematic/regular, or targeted sample site selection approaches. Systematic/regular sampling assigns sampling locations at regular distance intervals to ensure uniform coverage of each area (in this case, stream or river) of interest. Using the judgment/representative approach, sample sites are selected by best professional judgment to represent conditions across the population of interest. When making inferences beyond the sites sampled to other unsampled units in the population, judgment sampling risks producing biased, unreliable information (Olsen et al. 1999). Targeted sampling selects site locations to address specific questions, such as evaluating regulatory compliance at point-source discharges or evaluating restoration activities (Rehn and Ode 2009). Targeted sampling is not statistically based, but this does not compromise the study objectives provided unbiased population estimates are not required.

In considering the objectives of the proposed lower Clackamas River basin macroinvertebrate monitoring program relative to the sampling designs described above, a random sampling design does not appear necessary for the following reasons: Tracking water quality in tributaries to the Clackamas River in order to identify potential sources of changes in water quality in the river will necessitate sampling in all major tributaries. Furthermore, limited resources likely preclude monitoring of numerous reaches within tributaries. Accordingly, monitoring of tributaries for purposes of informing the source of potential threats to the lower Clackamas River should focus on establishing monitoring sites in the lower reaches of *each* tributary below all known point source discharges and any suspected non-point pollution sources. Targeted sample site selection would therefore be appropriate for tributary stream sampling, as *each* stream will be monitored. There will be no need to make inferences about conditions across a larger population of sites, as the entire population of interest will be monitored. Each of 9 larger Clackamas River tributary streams are proposed for inclusion in the monitoring program (Table 1, Figures 1-4). An additional four tributaries to the Clackamas River major tributaries are included in this targeted sampling design, as well (Figures 1-4). These tributaries were selected because they each also represent larger drainage areas in portions of the watershed with known or suspected water quality issues resulting from agriculture or ubanization.

Neither will long-term monitoring in the lower Clackamas River require a probabilistic sampling design. Rather, a targeted sampling design is recommended that will focus on monitoring macroinvertebrate community conditions in relation to municipal water intake locations. Five drinking water points-of-diversion (POD) are located along the lower Clackamas River (including one immediately upriver of the River Mill Dam) at river miles 0.8, RM 1.7, RM 2.7, RM 3.1, RM 22.7 (Figures 1-4). Furthermore, a single WWTP discharges directly into the Clackamas River immediately upriver of the River Mill Dam. Stations on the mainstem Clackamas River should be located to monitor water quality immediately upriver of PODs and bracketing WWTPs. Accordingly, a single site upriver of both the Estacada WWTP and Estacada POD will serve to monitor water quality entering the lower river from upriver (Table 2). Because the River Mill Dam also occurs in this immediate area, and a downriver location acting to bracket the Estacada WWTP would necessarily be located below the dam, any effects of the WWTP on biology in the mainstem may be confounded by effects of the dam. In light of this, the proposed location below the River Mill Dam could only serve to monitor the combined (and un-separable) effects of the dam and the WWTP.

Deep Creek enters the Clackamas River at RM 11.6, approximately midway between River Mill Dam and the uppermost of the series of 4 drinking water PODs in the lower 3.1 miles of river. Because Deep Creek carries treated effluent from the Boring WWTP (via North Fork Deep Creek) and seasonally from the Sandy WWTP (via Tickle Creek), monitoring the mainstem Clackamas River should also include sample stations bracketing this large tributary system.

Rock Creek enters the Clackamas River at RM 6.4. A long-term monitoring station is recommended on the river below the confluence with Rock Creek (Figures 1 and 2). This station could be sited in close proximity to the POD at RM 3.1 to monitor the quality of water being withdrawn at this POD. Another monitoring station is proposed for the lower river below the series of 4 PODs to monitor water quality flowing through this 2.3-mile-long section of river (Figures 1 and 2). This station serves to inform whether changes are occurring within this 2.3-mile-long section of river, along which water is being withdrawn for municipal use.

Temporal aspects of the sampling design in need of consideration include both timing (when time of year) and frequency (how often) of sampling. Macroinvertebrate monitoring, most often occurs in the late summer (late July) through early fall (late September/early October) period. Any sampling occurring under this plan for the purposes of trending biological conditions in the lower Clackamas River basin should occur during this time period.

Sampling frequency is another important aspect of the sampling design. Considerations in determining sampling frequency include the time period over which detection of change is desired, as well and the desired size of the change. Importantly, large data sets are typically required to allow detection of all but the largest of changes or trends in biological conditions over time, particularly when temporal variability of response variables is moderate to high (as can be the case with biological monitoring data). These data needs most often far outweigh available resources. As such, it is important to recognize that this monitoring program will not rely on exclusively on statistical trend analysis to detect trends. Rather, a combination of graphical approaches, statistical analysis, and professional judgment are recommended for identifying potential changes to biological conditions. Potential statistical approaches for analyzing multiple years of biological monitoring data for trends include simple linear regression or the non-parametric Mann-Kendall Test (Helsel and Hirsch 1991). The latter is typically preferred because various assumptions required for valid interpretation of the results from the parametric test are often not met when monitoring for temporal trends in environmental conditions (Helsel and Hirsch 1991).

Furthermore, changes to conditions may not occur as longer-term trends, but as a sudden deviation outside the range of conditions previously occurring at a site. Characterizing the natural temporal variability at a site is an important aspect in site-specific biological monitoring. Only by capturing and quantifying this temporal variability can one make inferences about changes or trends. As an example, consider an effort to monitor a stream reach for biological condition over a ten-year period. In this example, samples collected only in years 1, 5 and 10 may suggest a potential down-trending of biological conditions over the 10-year period (Figure 5, top). However, annual sampling reveals that this apparent trend occurs as a result of too-infrequent sampling relative to the time period over which any potential trend or change is to be detected (Figure 5, bottom). The small number of samples collected were insufficient to accurately portray conditions (and variability thereof) over the longer term.

While the foregoing example uses hypothetical data, biological conditions in the Clackamas River basin vary naturally within waterbodies over time. Repeated sampling of streams in the lower Clackamas River basin between 2007 and 2011 resulted in macroinvertebrate multimetric scores that ranged by as many as 8 points among years (Lemke and Cole 2011). Furthermore, current sampling techniques, while an attempt to fully represent the macroinvertebrate community within a particular stream reach at a given time, introduce a certain amount of sampling error that can result in differences in calculated community metrics between replicate samples (i.e., collected from the same location at the same time). For example, duplicate samples collected from north Willamette River basin streams averaged 2.5 multimetric points (on a scale of 10 to 50 points) and ranged from 0 to 6 points (n = 13; Cole 2002, Cole et al 2006, Lemke and Cole 2007, Lemke and Cole 2009). Together, this temporal and spatial variation reinforces the need for multiple measurements of biological condition over time when examining data for potential changes or trends in biological condition. As such, annual monitoring is preferred, and absolutely should occur no less often than every other year, at least initially in order to characterize year-to-year variation.

FIELD METHODS

Field methods should follow standard protocols employed by local, regional, and state agencies for purposes of quantifying the condition of macroinvertebrate communities in Oregon rivers and streams. Sampling from the wadeable tributaries should follow Oregon DEQ's standard operating procedures for sampling macroinvertebrates (OR DEQ 2003). Following this protocol will ensure that data are collected in a consistent, repeatable manner and allow confident comparison of data across locations and among years. OR DEQ uses a D-frame net with 500 µm mesh as the sampling device. The protocol targets riffle habitat, where macroinvertebrate diversity is highest and generally includes the highest abundance and richness of sensitive taxa. This protocol also ensures representativeness of the sample to the habitats sampled by collecting macroinvertebrates from 8 separate randomly-selected points within the sample reach. This composite sample represents 0.74 m^2 of the stream bottom. Sampling from the mainstem Clackamas River should largely follow the same protocols, but sampling will be restricted to shallow, wadeable portions of riffles, and will therefore not be entirely random across the larger habitat unit. Field sampling notes should explicitly identify the range of depths and water velocities sampled at each mainstem site.

LABORATORY METHODS

Laboratory processing of macroinvertebrate samples includes three steps: Sorting invertebrates from the sample matrix, subsampling to achieve a desired sample size, and identification. Sorting and subsampling usually occur simultaneously; that is, macroinvertebrates are sorted from the sample matrix until the desired target subsample is achieved. Because taxonomic richness increases with increasing subsample size, consistency among samples, sites, and studies is required for making comparisons. OR DEQ currently uses a 500-organism target subsample size. Analyses currently in use in Oregon for determining the condition of benthic macroinvertebrate communities require a 300 or 500-organism subsample. A 500-organism subsample is recommended for this monitoring program.

The taxonomic level to which macroinvertebrates are identified is one of the most important determinants of data utility and comparability. The Oregon Water Quality Monitoring Guidebook (WQIM 2001) currently recognizes three levels of resolution that correspond to increasingly discriminatory power for detecting levels of biological impact. Level I taxonomy is the coarsest level and requires aquatic insects be identified only to order (mayfly, stonefly, caddisfly, etc.). At this level, only the broadest of inferences can be made regarding community condition. This level has no value for trending water quality conditions relative to the stated objectives of this monitoring program. Level 2 requires identification of aquatic insects to the family. While this approach allows better discrimination of condition levels, it is still limited in its ability to detect all but the largest of changes. Level 3 assessments require aquatic insects be identified to genus/species, as much as keys and specimen condition allow. OR DEQ routinely uses Level 3 identification in their assessment work, and now also includes identification of Chironomidae to genus/species. Each of the existing analysis tools discussed next utilize exclusively Level 3 data. Level 3 taxonomic effort is recommended for this monitoring program. Furthermore, Chironomidae should be identified to genus/species in the event that future assessment tools are developed that utilize this genus/species-level information for this family.

DATA ANALYSIS

A number of standardized analysis approaches exist for assessing the condition of macroinvertebrate communities in Oregon. These approaches can be broadly classified as multimetric indexes and predictive models. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that has been shown to be associated with one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is an index of overall biological integrity. Two multimetric indexes are routinely applied in wadeable streams of western Oregon (WQIW 2001): one index (the Level 2 Assessment) is intended for use with family-level data and provides a coarse classification of biological condition, while the second index (the Level 3 Assessment) uses genus and species-level data and provides a finer level of conditions classification (none, slight, moderate, and severe).

The Level 3 assessment utilizes a 10-metric set that includes six positive metrics that score higher with improved biological conditions, and four negative metrics that score lower with improved conditions (Table 3). The Modified Hilsenhoff Biotic Index (HBI), originally developed by Hilsenhoff (1982), computes an index to organic enrichment pollution based on the relative abundance of various taxa at a reach. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a macroinvertebrate community more tolerant to fluctuations in water temperature, fine sediment inputs, and organic enrichment. Sensitive taxa are those that are intolerant of warm water temperatures, high sediment loads, and organic enrichment; tolerant taxa are adapted to persist under such adverse conditions. The DEQ taxa attribute coding system was used to assign these classifications to taxa in the data set (DEQ, unpublished information).

This second index was widely used by Oregon DEQ to assess biological conditions in wadeable western Oregon rivers and streams, but has recently and largely been supplanted by the predictive model approach, known as PREDATOR in Oregon. PREDATOR is a predictive model that evaluates macroinvertebrate community conditions based on a comparison of observed (O) to expected (E) taxa (Hawkins et al. 2000, Hubler 2008). The observed taxa are those that occurred at the site, whereas the expected taxa are those commonly occurring (>50% probability of occurrence) at reference sites. Three regional PREDATOR models are currently in use in Oregon; one of these three models - the Marine Western Coastal Forest (MWCF) Predictive Model – encompasses the Willamette Valley and Coast Range ecoregions (Hubler 2008). Biological condition is determined by comparing the O/E score to the distribution of reference reach O/E scores in the model. One major strength of PREDATOR over the multimetric approach is that a single predictive model can be constructed to assess biological conditions over a wide range of environmental gradients such as stream slope, longitude, or elevation, whereas separate multimetric tools would have to be developed to more accurately assess condition over this wide range of natural environmental gradients. PREDATOR is able to predict taxonomic composition across a range of naturally occurring environmental gradients with discriminant functions models (DFMs). Discriminant functions analysis is used during the model building phase to identify the environmental variables that are statistically related to natural gradients in macroinvertebrate community composition (Hawkins et al. 2000). These "predictor variables" are then used in the resulting model to predict macroinvertebrate community composition in the absence of disturbance. The model assigns a probability of class membership of each test site to the different classes of test sites specified in the model based on the environmental predictor variables that are input into the model.

Neither the multimetric index nor the PREDICTIVE models have been developed for use on rivers as large as the lower Clackamas, a consequence of larger rivers in the region having been uniformly affected by human impacts. Use of these tools is recommended for the lower Clackamas River tributary streams, but assessment of the mainstem Clackamas River will necessitate an approach by which a number of individual metrics, each known to be responsive to human disturbance, are individually monitored over time, rather than being combined into a single overall index of condition. PGE's 2004 study of the mainstem Clackamas River used this approach, which can serve as useful guidance for selection of specific metrics.

REVIEW OF EXISTING DATA

Macroinvertebrate community assessments have routinely occurred in the lower Clackamas River basin since the late 1990s. While no single entity has consistently monitored macroinvertebrate communities within the basin during this period, the collective efforts of numerous agencies may potentially allow for some trending of stream conditions. This review was performed to determine to what extent previous studies could inform past conditions and trends in water quality at priority long-term monitoring locations. Since the late 1990s, macroinvertebrate assessments in the lower Clackamas River and/or its tributaries have been performed by the University of Washington (UW), Portland General Electric (PGE), Clackamas County Water Environment Services (WES), OR DEQ, Clackamas River Basin Council (CRBC), Clackamas Soil and Water Conservation District (Clackamas SWCD), United States Geological Survey (USGS), Portland State University, Portland Metro Regional Services (Metro), and Portland State University (Table 3). The information and data obtained from these various studies may well serve to inform, at least partially and retrospectively, the objectives of the CRWP macroinvertebrate long-term monitoring plan. In order to determine the utility of these data, an objective review and evaluation of their suitability relative to the stated objectives of this plan was necessary.

REVIEW CRITERIA

A request for data and other information was made to each of the above agencies and entities. Monitoring and assessment efforts were summarized in tabular and narrative formats to assist with the review. To perform the review, a set of criteria was developed for reviewing data and determining their suitability for achieving stated project objectives. Criteria were established for the following study design elements: field methods (sample device and method, habitat(s) sampled, area sampled, season), laboratory methods (sample processing and subsampling methods, taxonomic resolution) and data analyses used.

FIELD METHODS

A number of devices are used to sample macroinvertebrates from running waters. Commonly employed quantitative and semi-quantitative sampling devices include D-frame nets, Surber samplers, slack samplers, and Hess samplers. Each of these, if properly used, allows estimates of both relative abundance and densities of macroinvertebrates. State agencies and others engaged in water quality assessment aimed at determining whether water quality criteria are met use semi-quantitative or quantitative sampling methods. Use of these sampling methods is required for determining the diversity and relative abundance of macroinvertebrates with a sufficient level of resolution for use with standard benthic community analysis approaches. Studies that did not use one of these quantitative or semi-quantitative sampling devices could not be considered for inclusion in the long-term monitoring data set.

Biological monitoring in rivers and streams generally focuses sampling efforts in the most productive and diverse habitats: riffles. Most monitoring programs, including those currently used by OR DEQ, focus sampling in these habitats. Whether to sample from all habitats or only the most productive habitats is currently a subject of debate, but because current analysis tools utilize data collected from riffles, only data from these habitats should be included in any comparative monitoring effort.

Macroinvertebrate communities are not evenly distributed across the stream bottom. Rather, their distribution can be rather patchy, varies among taxa, and is affected by myriad interacting variables. As such, a sufficient area of stream bottom must be sampled in order to gain a representative sample of the reach or habitat of interest. Highly variable sampling effort among studies introduces another element of variability in response variables (multimetric or PREDATOR scores) that results in less reliable comparisons of results from different studies. An examination of sampling methods employed by various Pacific Northwest state and federal agencies suggests that this effort is uniformly 0.74 m^2 or higher. As previously discussed, OR DEQ's 8-kick composite method represents 0.74 m^2 of stream area. Sampling efforts that result in substantially less sampled area are likely to collect fewer taxa and potentially also result in biased relative abundance estimates. Such samples will add an unknown amount of variability to estimates of community condition and potentially obscure or confound changes or trends in condition. For purposes of this evaluation, samples collected from areas less than 0.5 m2 were identified as potentially compromised data in need of further examination before they could be included in the data set.

Macroinvertebrate communities are known to vary in their composition through the year, a result of highly variable timing of life cycle events among taxa. In order to make comparisons among years and detect trends over time, sampling must occur within a limited (seasonal) time period to ensure the same assemblage of animals is sampled each year. In the Pacific Northwest, sampling for macroinvertebrates typically occurs between July and October. Accordingly, data collected outside of this seasonal window were not considered for inclusion in the long-term monitoring dataset.

LABORATORY METHODS

Most professional monitoring in the Pacific Northwest utilizes a 500-organism subsample. Volunteer monitoring efforts, such as those supported by the Oregon Watershed Enhancement Board (OWEB), often use smaller subsample sizes of 300 organisms. OR DEQ's PREDATOR model only requires a 300-organism subsample. For purposes of inclusion in the long-term monitoring dataset, 500 organisms was most desirable, but 300-organism datasets were retained for potential use, as later discussed.

The taxonomic level to which macroinvertebrates are identified is one of the most important determinants of data utility and comparability. Any studies using Level 1 data were excluded from further consideration of inclusion in the monitoring data set. Level 2 data were flagged as potentially having limited value for coarse monitoring of large changes, but should only serve to inform general conditions where more comprehensive data do not currently exist.

HABITATS SAMPLED

Existing multimetric and predictive models have been developed from and are therefore only appropriate for use with macroinvertebrate data derived from riffle samples. Community information collected from other habitat types would lead to erroneous analysis results. Accordingly, data must be collected from riffles for proper application of the models and interpretation of their results. Only samples collected from riffle habitats would be included in the long-term monitoring data set. Importantly, as long as the data collected meet the above criteria, prior analyses conducted are unimportant because analyses using these standardized approaches can still occur to allow meaningful comparisons over space and time.

REVIEW RESULTS

All known existing macroinvertebrate data from the lower Clackamas River basin were evaluated for their utility for long-term (LT) monitoring based the preceding criteria. Each of these elements was evaluated based on the following scaling system: 1) effort/resolution entirely sufficient for inclusion in LT data set, 2) effort/resolution potentially sufficient for LT data set, but further examination necessary, 3) effort/resolution appropriate only for coarse evaluation/trending, 4) effort/resolution insufficient for inclusion in any LT data set relative to the objectives of this monitoring plan. A final long-tern trending ranking (LTR) was assigned to each dataset based on the lowest score received among the individual criteria (Table 4). The following narratives describe each study relative to these criteria and explain whether each study meets the criteria to be included in long-term monitoring for purposes related to this plan.

UNIVERSITY OF WASHINGTON 1997-1998 MACROINVERTEBRATE STUDY

University of Washington graduate student Jeff Adams performed an assessment of macroinvertebrate communities in the Clackamas River basin in 1997 and 1998. A total of 44 locations within the basin were sampled, 17 of which occurred within the lower Clackamas River basin. Targeted sample site selection was used to ensure sampling over a range of land-use intensities throughout the entire basin (Adams 2001). Sampling was performed in late summer/early fall using a surber sampler in riffle habitats. Three surber samples were collected in each riffle, each representing 0.09 m2 of stream area. These three samples were processed as separate replicates before the Puget Sound Lowlands Index of Biotic Integrity was applied to the data. Raw taxonomic and count data were expressed as the average value of the three replicates. As such, richness values are likely biased low relative to what they would be if derived from a composite sample representing a larger stream area. Furthermore, 1997 samples do not meet Oregon Level 3 taxonomic effort (Chironomidae left at family), potentially limiting the use of the 1997 data to a coarser evaluation of condition. The 1998 data meet Level 3 taxonomic effort criteria. As such, for purposes of using these data for comparative long-term trending, these data should be re-analyzed by first pooling the replicate data, rarifying to a 500-organism subsample, and applying the PREDATOR model and DEQ western Oregon multimetric index. It should be noted that the smaller surface area represented by the 3 Surber samples may continue to introduce some bias into the analysis results, even after these steps are taken. Accordingly, this study receives a long-term trending ranking (LTR) of 2 (Table 4).

USGS MACROINVERTEBRATE ASSESSMENTS

The USGS has performed two studies since the late 1990s that included sampling macroinvertebrates from the lower Clackamas River basin. The first, performed in 1999 was conducted as a follow-up to their 1997-1998 algae study in the basin (Carpenter 2003). The study also sought to fill in the few data gaps left by the 1997-1998 Jeff Adams study (Kurt Carpenter 2013, personal communication). Nine study sites were included in the lower Clackamas River basin. Field methods employed a slack sampler in riffle habitats, sampling a total of 0.75 m^2 of stream bottom. The second study, performed in 2004, examined relationships between urbanization of watersheds and ecological conditions. This study included selected watersheds from throughout the Willamette basin. Four sites were sampled in the lower Clackamas River basin. Field methods included a 5-composite slack sample from riffle habitats, representing 1.25 m^2 of stream area. For both studies, laboratory methods included a 500-organism subsample and taxonomic effort that exceeded OR Level 3 (Chironomidae were identified to genus/species). A series of individual metrics were calculated for determination of macroinvertebrate communities. These data have not yet been published by the USGS. Both USGS studies receive an LTR of 1 (Table 4).

OREGON DEQ MACROINVERTEBRATE ASSESSMENTS

Since 1999 Oregon DEQ has assessed macroinvertebrate communities in the lower Clackamas River basin at 20 sites. These sites have been randomly selected as part of their obligation to assess water quality in waterbodies within the state. OR DEQ employs standard sampling and laboratory methods, all of which meet the criteria in this document. Data from many of these sites were originally analyzed using the western Oregon multimetric index, but have since been analyzed using the MWCF PREDATOR model. All OR DEQ data receive an LTR of 1 (Table 4).

PORTLAND GENERAL ELECTRIC 2000-2001 MACROINVERTEBRATE ASSESSMENT

Portland General Electric performed an assessment of macroinvertebrate communities in the basin in 2000 and 2001. This study focused on the middle and upper basin, but also included sampling in the mainstem Clackamas River below River Mill Dam. Sampling occurred at 44 sites throughout the basin; 5 of these sites occurred in the lower Clackamas River basin, all in the mainstem Clackamas River. Sites were selected to represent a range of altitudes and along a longitudinal profile from above all PGE developments to below the PGE project-affected area (Wisseman and Doughty 2004). Shallow riffle habitats were sampled in the mainstem river at four of five of these sites employing a 5-kick composite sample technique, representing 1 m^2 of river bottom. A single composite shallow-riffle sample was collected from each site. Samples were subsampled to remove 500 organisms; all organisms were identified to lowest practical taxonomic levels (exceeds OR Level 3 taxonomic criteria). Analysis employed a large number of individual community metrics to examine longitudinal trends and changes in river conditions. This study receives an LTR of 1. These data will serve as a useful baseline of conditions in the lower Clackamas River in the early 2000s.

WES 2002, 2007, 2009, 2011 MACROINVERTEBRATE ASSESSMENTS

Clackamas WES has been performing macroinvertebrate assessment and monitoring in the lower Clackamas River basin since 2002. Their assessment area includes all of Clackamas County Service District #1, which partially occurs in the lower Clackamas River basin. Sampling has occurred in 2002, 2007, 2009, and 2011; and the number of sites occurring within the lower basin has ranged between 6 and 8 each sampling year (Cole 2003, Lemke and Cole 2008, Lemke and Cole 2010, Lemke et al. 2012). Study sites have been selected to represent a range of land uses and also based on ease of access and co-occurrence with WES water-quality monitoring locations. These studies have consistently employed OR DEQ 8-kick composite sampling techniques and have collected from riffles whenever the habitat was present. Samples are subsampled to 500 organisms and Oregon Level 3 taxonomic effort is employed. Data analyses in 2002 was limited to the western Oregon multi-metric index, but in later years included both the multimetric index and PREDATOR model. These data from the 2002-2011 WES studies receive an LTR of 1 (Table 4).

METRO 2003 DAMASCUS AREA MACROINVERTEBATE ASSESSMENT

In 2003 Portland Regional Metro Services performed an assessment of macroinvertebrate communities in the planned urban growth boundary (UGB) expansion in the Damascus area. This study aimed to establish a comprehensive pre-UGB expansion baseline of ecological conditions (Cole 2004). Thirty-four of 40 study sites were located within the lower Clackamas River basin, including 6 sites on the lower Clackamas River and 28 sites on tributary streams. Sites were selected to examine longitudinal trends in conditions in all major tributaries within the Damascus area. Sites were relatively evenly distributed along the length of the tributaries (when multiple sites were sampled); selection was also dictated by landowner permission. Sampling occurred in the early fall and followed OR DEQ standard methods, collecting 8-kick composite samples from riffles. Laboratory methods included a 500-organism subsample and identification to OR Level 3 resolution. Data were analyzed using the DEQ western Oregon multimetric index. This study receives an LTR of 1.

CLACKAMAS RIVER BASIN COUNCIL

The CRBC has been performing macroinvertebrate monitoring of select streams within the lower Clackamas River basin since 2010. In both 2010 and 2011, 4 tributary sites were sampled, including Clear Creek, Foster Creek, North Fork Deep Creek, and Spring Creek. Using LASAR, these sites were selected based on information gaps in the DEQ database. Sampling was performed using a 3-kick composite sample, representing 0.27 m^2 of stream bottom. Subsampling used a target count of 300 organisms, and family level (OR Level 2) taxonomic resolution was used. The OR Level 2 multimetric index (WQIW 2001) was used to summarize and analyze the data. Sampling from the smaller stream area and the limited resolution in the taxonomic data allow these data to be used only for a more coarse assessment of stream condition. These data receive an LTR of 3.

CLACKAMAS SOIL & WATER CONSERVATION DISTRICT

In 2012 the Clackamas SWCD contracted an assessment of macroinvertebrate communities in the North Fork Deep Creek and Noyer Creek drainages (Haxton and Cole 2012). Sites were selected to fill in local information gaps and were also determined by accessibility.

Tickle Creek was selected to represent the local reference (least disturbed) condition. The 5 sites were samples using standard OR DEQ methods, including collection of an 8-kick composite sample from riffle habitats. Laboratory processing included a 500-organism subsample and OR Level 3 taxonomic resolution. Data were analyzed using the western Oregon multimetric index, the MWCF PREDATOR model, and the OR DEQ stressor models. These data receive an LTR of 1.

PORTLAND STATE UNIVERSITY

Portland State University currently engages in two separate monitoring efforts in the lower Clackamas River Basin. First, PSU supports the Student Watershed Research Project (SWRP), an ambitious effort by local high schools to monitor water quality in area streams. The macroinvertebrate component of the SWRP monitoring limits identification of insects to order. Other elements of the program were not reviewed in this exercise, as the taxonomic level precludes further consideration for inclusion in the long-term trending dataset. SWRP macroinvertebrate monitoring should still be encouraged for the important environmental education and stewardship purposes it serves.

Since 2010 PSU has been monitoring macroinvertebrate communities from 3 sites (lower Rock Creek, lower Clear Creek, and middle Clear Creek) in the lower Clackamas River basin (Patrick Edwards, PSU, personal communication). These sites are sampled by PSU students, each student group sampling from 0.27 m^2 of stream bottom using a 3-kick composite sample. Sampling has been conducted from early fall into December. Sampling effort varies among sites and years, apparently driven by the number of student teams collecting at each site. Macroinvertebrates from each sample are subsampled to a target count of 300 organisms, and then identified to OR Level 2 (insects to family). Data from subsamples are pooled before calculation of OR Level 2 community metrics, resulting in estimates likely biased by the total number of samples collected by students at each site. Owing primarily to the Level 2 taxonomic effort, these data receive an LTR of 3 and should be considered suitable for coarse evaluation of long-term trends in conditions at these study sites.

PLANNED MONITORING

Presently, immediate plans for continued macroinvertebrate monitoring in the lower Clackamas River basin and limited to the CRBC and Portland State University (PSU). The CRBC will be using OR 8-kick collection techniques and will be sending their samples out for professional identification to OR Level 3 taxonomic effort. CRBC presently plans to sample from 7 sites in the lower Clackamas River basin. Because PSU will not be performing taxonomic work beyond family level and will be limiting analyses to the OR Level 2 index, these efforts will not be included in a gap analysis (i.e., PSU sample sites will be treated as unsampled for purposes of comparative long-term trending in the lower basin). Clackamas WES has tentative plans to continue macroinvertebrate monitoring in the lower Clackamas River basin, but locations and frequency are currently unknown.

DATA GAP ANALYSIS

Following the review of all existing data and identification of others' planned efforts, a data gap analysis was performed to determine the extent to which past and planned efforts address monitoring needs as identified in this plan. First, existing sample locations were assigned to proposed long-term monitoring locations, and then the effort within each LT monitoring location was summarized by year and LTR separately for tributaries (Table 4) and the mainstem Clackamas River.

Among 13 proposed tributary LT monitoring locations, only 4 stations include 4 or more years of LTR-1 macroinvertebrate data collected between 1997 and 2012. Three of these 4 locations – Richardson, Rock, and Sieben creeks – are priority 1 monitoring locations. One location, lower Tickle Creek, was sampled three times but across a relatively narrow period (1998-2004). Of the remaining proposed tributary LT monitoring locations, 2 have been sampled twice and 6 have been sampled only once (Table 4). As such, no opportunities exist for even a casual examination of trends over the 1998-2012 period at most proposed tributary LT monitoring locations.

Furthermore, plans for future monitoring at these locations are currently limited. CRBC will sample macroinvertebrates from 7 locations in the lower Clackamas River basin in 2013

(Rebecca Walker, CRBC, personal communication). Two of these sites overlap with proposed tributary LT monitoring locations, as indicated by asterisks on Table 5.

Macroinvertebrate assessments of the lower Clackamas River have generally been lacking. Only three studies are known to have included macroinvertebrate sampling from the lower river. The USGS sampled 5 sites in the lower river in 1999; PGE sampled from 5 sites in 2000; and Portland Metro sampled from 6 sites in 2003. USGS stations occurred throughout the lower section of the river from the mouth upriver to the River Mill Dam. PGE locations occurred exclusively upriver of the confluence of Clear Creek and the Clackamas River, while the Portland Metro stations occurred only below the confluence of Eagle Creek and the Clackamas River. Among six mainstem reaches identified as proposed LT monitoring locations, these efforts collectively provide two years of data at three stations (below River Mill Dam, above Deep Creek, and below Deep Creek). Only one year of data exist for the two proposed lower-most stations (near the mouth and below Rock Creek) and the single station above River Mill Dam. These data sets are currently sufficiently limited so as to preclude making any inferences about past trends in mainstem river macroinvertebrate community conditions. Furthermore, no planned efforts for macroinvertebrate monitoring are known. As such, macroinvertebrate conditions in the lower Clackamas River and trends in those conditions are a significant data gap in need of attention.

RECOMMENDED MONITORING STRATEGY

A review of past monitoring efforts relative to the proposed sampling locations for long-term monitoring of the lower Clackamas River basin reveals significant spatial and temporal data gaps, both past and future. While macroinvertebrate assessments have been performed at most proposed monitoring locations at one time or another, few sites have more than 2 years of associated data over the 15-year period between 1997 and 2012. As such, significant new efforts will be required to produce robust data sets capable of detecting changes or trends in benthic macroinvertebrate communities in the lower Clackamas River basin. Moving forward, these efforts should focus on sampling from the 8 priority tributary and 6 mainstem river locations listed in Tables 1 and 2. To the extent possible, monitoring should occur annually or bi-annually to produce sufficient data that will allow for determination of larger trends over time periods spanning 5-10 years.

Importantly, the collection of single samples at monitoring sites will significantly limit the ability to detect-short term changes (i.e., changes in condition from one year to the next). As previously discussed, potentially large inter-annual variability may allow only relatively large differences (e.g., multimetric index score changes >10) between years to be identified as likely changes in biological condition. Because collection and processing of replicate samples from each site adds considerably to monitoring costs, performing replicated sampling was not considered in this initial version of the monitoring plan. If the CRWP decides that detection of smaller inter-annual changes in condition is desired, this design element could be further explored, including conducting a power analysis to determine how large a change would be necessary to be detected at a given sample size and between-sample variance.

Collection of single samples at each station at regular intervals (annual, bi-annual) will result in a data set in which each location can be evaluated for trends in declining (or improving) conditions over time using the Mann-Kendall trend test. This trend analysis tool requires multiple measurements (larger number of observations results in higher power). Therefore, sampling at intervals of longer than two years will present a significant impediment to trend detection. If monitoring for detection of declining conditions over time at each location is of primary concern, and the number of proposed locations precludes annual or biannual sampling at each, then fewer monitoring stations should be considered. Achieving this balance between the number of sampling stations and the sampling frequency will be an important consideration in finalizing a long-term monitoring strategy.

One design issue not yet considered is whether to include one or more least disturbed or "reference" locations. Reference stations are intended to describe the best attainable condition for the remaining "test" sites and allow some quantification of deviation from a least disturbed condition. To a certain degree, the existing macroinvertebrate community assessment tools (PREDATOR and the OR DEQ multimetric index) already accomplish this by comparing computed "test site" values to those already derived from regional reference stations. For this proposed monitoring program, what's needed is a means for discriminating natural year-to-year variability from changes induced by human activities. Because the population of test sites (all major tribs to the lower Clackamas River) will all be sampled in each year, and some will experience more degradation than others, comparisons made among stations within the study group should serve this purpose well. Simply put, in any given year, the condition at some stations will decline, while at others will remain stable. However, at least one reference location could serve longer-term trending well if the lower extents of all tributaries were eventually further degraded by upstream development (perhaps not an unlikely eventuality). In such a case, determining whether these trends were likely related to conditions unique to the sampled test tributaries or occurring at some larger regional scale would require one or more reference stations that remain un-manipulated for the duration of the monitoring program. If funding allows, establishing at least one lower Clackamas River basin regional tributary reference station is recommended.

Ultimately, the success of this proposed monitoring program depends on developing and executing a well thought strategy that is explicitly tied to the monitoring objectives. This plan lays the technical foundation for ensuring the collection of valid data of sufficient rigor, including sampling design, field and lab methods, and analysis. Only through a consistent, long-term commitment to the plan will requisite data be produced. As such, careful thought must be given to the ability to commit resources to this endeavor over the longer term. Depending on available resources, fewer monitoring stations may be necessary to ensure that a sufficient quantity of data is collected from each station. The CRWP should use their knowledge of known and potential threats to water quality in the lower basin to further prioritize monitoring stations should the need to reduce the number of stations arise.

The ability to commit to this endeavor over the long term will partially depend on associated costs. Contracting out these services typically costs as much as $1500-$2000 per site per year, including field work, lab work, analysis, and reporting. Field work normally includes collection of physical habitat and water chemistry data, in addition to collection of macroinvertebrate samples. If staff from basin partners can be trained in field sample collection, costs could be reduced significantly, potentially requiring only laboratory processing of the samples to be contracted. In addition to field sample collection, staff would also require training in physical habitat assessment procedures, which tend to occupy most of the time at a site visit. Up-front costs would necessarily be incurred, and would primarily include equipment puchases (kick nets, water chemistry meters, ancillary gear and supplies). If only lab work would be contracted, costs could potentially be reduced to $300-400 per sample. Contracted lab-only services would typically include data summary and analysis using standard analysis tools discussed in this plan. One approach worth considering may to collect samples annually or every two years, but collect physical habitat data less frequently (such as every 3 to 5 years). This would reduce costs by allowing basin partner staff to perform most of the field sampling, but would incorporate a more comprehensive effort at 3-to-5-year intervals that would include physical habitat sampling, potentially performed by a contractor.

Based on the needs identified in this plan and the availability of funding for sampling from a handful of locations in fall 2013, we recommend sampling from the proposed mainstem Clackamas River sites this fall. Focusing entirely on the mainstem this fall will allow a complete assessment of the lower river (as suggested in this plan) and will provide the necessary data to begin to characterize spatial and temporal variability in the lower river, a very important aspect of long-term monitoring of the lower mainstem Clackamas. Tributary sampling should occur only after this plan has been shared with basin partners and opportunities for collaborative monitoring of the tributaries have been identified and implemented.

Even in advance of sampling this fall, CRWP should begin sharing this plan with basin partners to identify opportunities for collaborative monitoring efforts that will meet the needs of each partner. Other current monitoring efforts in the basin, such as those by PSU, WES, and CRBC, offer significant opportunity for leveraging these proposed efforts. To the extent possible, aligning monitoring stations with those proposed in this plan and using common field and lab methods will provide much needed support to this proposed long-term monitoring effort.

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Table 1. Proposed sample locations for monitoring tributary streams to the lower Clackamas River. Priority 1 locations should be sampled according to the guidelines recommended in this plan. Priority 2 locations can be sampled less frequently if resources are insufficient to allow monitoring at the same frequency as priority 1 locations.

Water Body	Location	Tributary To	Priority
Clear Creek	lower	Clackamas R	1
Deep Creek	US NF Deep Creek	Clackamas R	1
Eagle Creek	lower	Clackamas R	1
North Fork Deep Creek	lower	Deep Creek	1
Richardson Creek	lower	Clackamas R	1
Rock Creek	lower	Clackamas R	1
Tickle Creek	lower	Deep Creek	1
Sieben Creek	lower	Clackamas R	1
Cow Creek	lower	Clackamas R	2
Deep Creek	US Tickle Creek	Clackamas R	2
Doane Creek	lower	North Fk Deep Crk	2
Foster Creek	lower	Clackamas R	2
Noyer Creek	lower	Deep Creek	2

Table 2. Proposed long-term macroinvertebrate monitoring locations on the lower mainstem Clackamas River.

Approx RM	Location	Rationale
23.0	Above River Mill Dam	monitor WQ entering lower mainstem
22.0	Below River Mill Dam	bracket Estacada WWTP and River Mill Dam
12.0	Above Deep Creek confluence	bracket Deep Creek system
11.0	Below Deep Creek confluence	bracket Deep Creek system
4.0	Below Rock Creek	monitor WQ immed upriver of PODS
0.5	near mouth	monitor WQ immed downriver of PODs

Table 3. Summary of past macroinvertebrate monitoring efforts occurring in the lower Clackamas River basin. Total number of sites includes all sites both inside and outside of the lower Clackamas River basin.

Year(s)	Season	Agency	Total # Sites	# Sites w/in lower Clackamas Basin
1997-1998	Fall	UW	44	17
2000-2001	Summer/Fall	PGE	44	5
2002	Fall	WES	14	6
2003	Fall	Metro	40	34
2007	Fall	WES	14	7
2009	Fall	WES	16	8
2011	Fall	WES	23	8
2011	Fall	CRBC	4	4
2012	Fall	Clackamas SWCD	5	5
1999	Fall	USGS	many	9
2004	Fall	USGS	28	4
1998-2009	Summer/Fall	DEQ	many	20
2010-2012	Various	PSU	5	3
1993-2012	Spring or Fall	SWRP/PSU	many	22

Table 4. Effort summary of macroinvertebrate assessments occurring in the lower Clackamas River basin since 1997. OR Taxonomic Levels: 1 = order, 2 = family, 3 = genus/species (Chironomidae may still be at subfamily/tribe). Analyses: MM = multimetric analysis, PR = PREDATOR model, ST = stressor models, DEQ LV2 = level 2 multimetric analysis.

Year(s)	Agency	# Sites w/in Study Area	Sampling Method	Area Sampled	Reps/Site	Subsample Size	OR Taxonomic Level	Analyses	Long-term Trending Ranking
1997-1998	UW	17	Surber	0.27 sq m*	3	None	1997: 2/3 1998: 3	MM: averaged raw metric scores from each rep	1997: 3, 1998: 2
2000-2001	PGE	5	5-kick composite (4 of 5 sites)	1 sq m	1	500	3	indiv metrics	1
2002	WES	6	8-kick composite	0.75 sq m	1	500	3	MM	1
2003	Metro	34	8-kick composite	0.75 sq m	1	500	3	MM	1
2007	WES	7	8-kick composite	0.75 sq m	1	500	3	PR, MM	1
2009	WES	8	8-kick composite	0.75 sq m	1	500	3	PR, MM, ST	1
2011	WES	8	8-kick composite	0.75 sq m	1	500	3	PR, MM, ST	1
2011	CRBC	4	3-kick composite	0.27 sq m	1	300	2	MM: DEQ LV 2	3
2012	Clackamas SWCD	5	8-kick composite	0.75 sq m	1	500	3	PR, MM, ST	1
1999	USGS	9	3-slack sampler composite	0.75 sq m	1	500		indiv metrics	1
2004	USGS	4	5-slack sampler composite	1.25 sq m	1	500	3	indiv metrics	1
1998-2009	DEQ	20	8-kick composite	0.75 sq m	1	500	3	PR, ST	1
2010-2012	PSU	3	3-kick composite	0.27 sq m	variable	300**	2	MM: DEQ LV 2	3
1993-2012	SWRP/PSU	22					1	??	4

Table 5. Number of past sampling events by year and long-term priority ranking (LTR) of existing data in each proposed lower Clackamas River basin long-term monitoring location (tributaries only, no Clackamas River mainstem sites). Grey shading denotes proposed locations with existing data receiving an LTR of 1 (indicating the data are suitable for inclusion in long-term monitoring efforts). Asterisks (*) indicate locations included in planned assessments for 2013.

LT Monitoring Location	LTR	1997	1998	1999	2002	2003	2004	2007	2009	2010	2011	2012	2013	Total
Deep abv NF Deep	1					1								1
Deep abv Tickle	1			3										3
	2	1												1
Lower Clear	1			1										1
	3										1			1
Lower Cow	2				1			1	1		1			4
Lower Doane	1											1		1
Lower Eagle	1			1									*	1
Lower Foster	2	1											*	1
	3									1	1			2
Lower NF Deep	1					1	1							2
	2	1												1
	3									1	1			2
Lower Noyer	1		1			1								2
Lower Richardson	1		1		1	1		1	1		1			6
	2	1												1
Lower Rock	1		1		1	1		1	1		1			7
	2	1												1
	3									1	1	1		3
Lower Sieben	1				1			1	1		1			4
Lower Tickle	1		1	1			1							3
	2	1												1

Figure 1. Map of the lower Clackamas River Basin past macroinvertebrate sampling locations and proposed long-term monitoring locations.

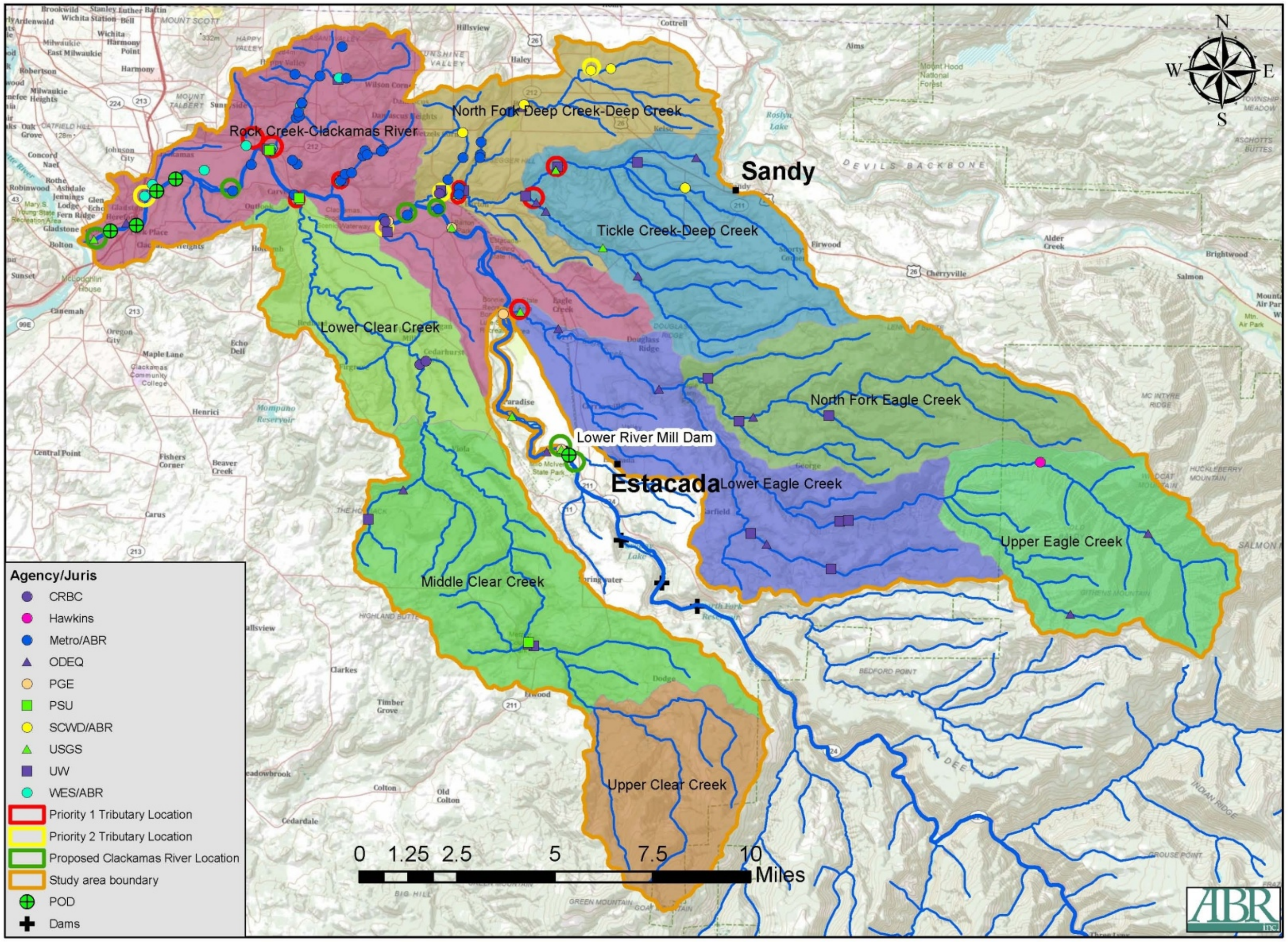

Figure 2. Map of the north-west section of the lower Clackamas River Basin past macroinvertebrate sampling locations and proposed long-term monitoring locations.

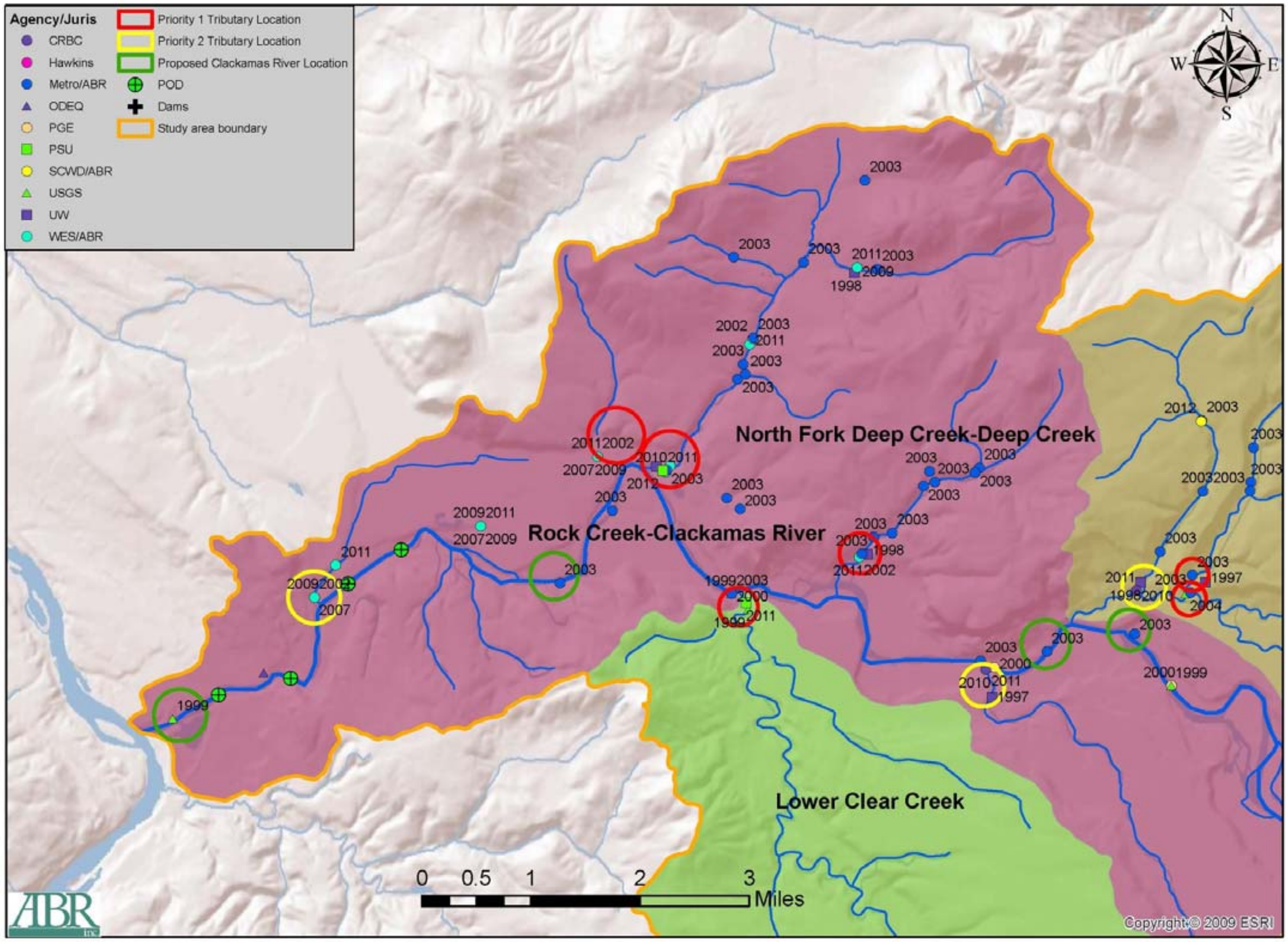

Figure 3. Map of the north-central section of the lower Clackamas River Basin past macroinvertebrate sampling locations and proposed long-term monitoring locations.

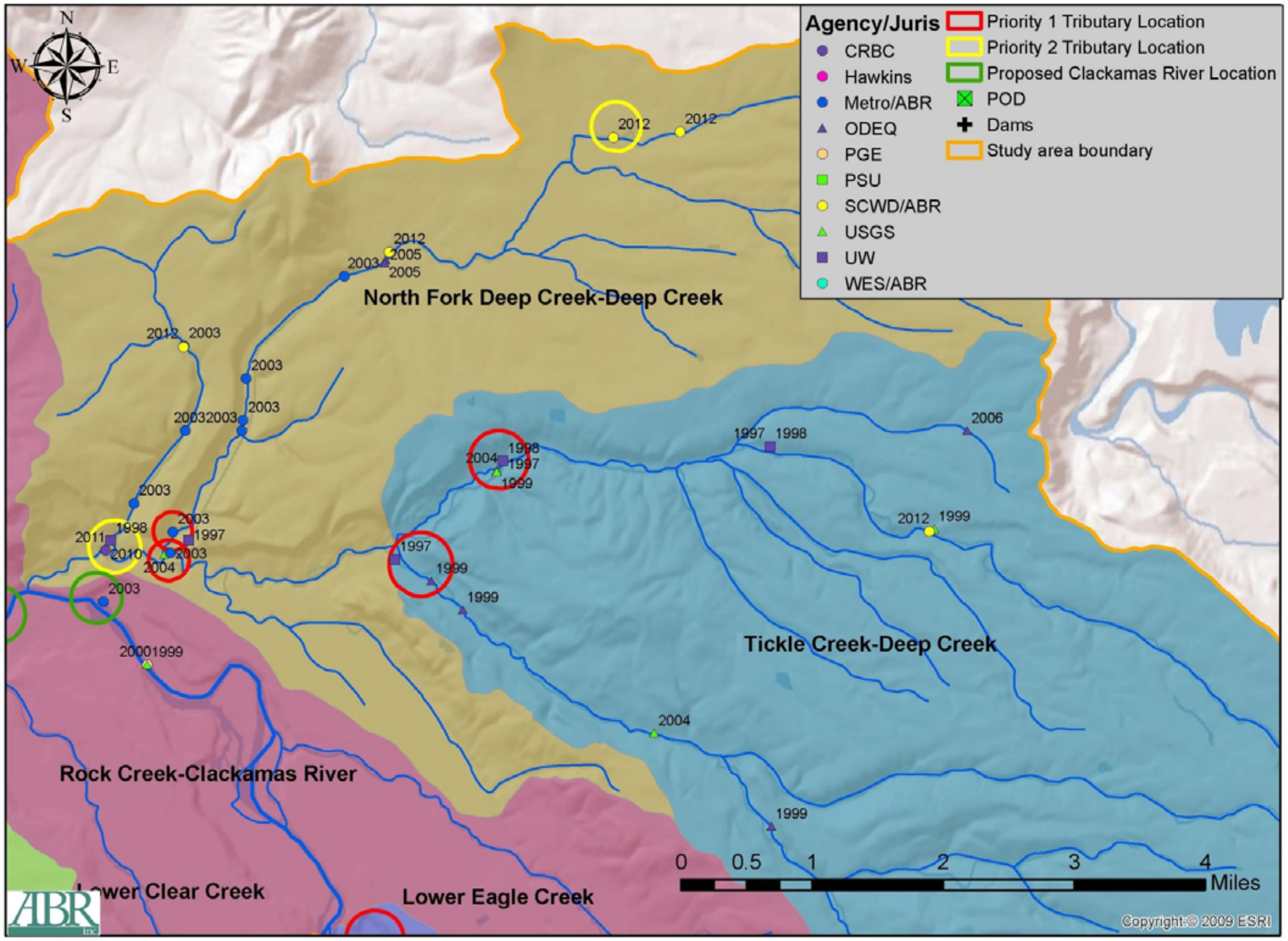

Figure 4. Map of the south-central section of the lower Clackamas River Basin past macroinvertebrate sampling locations and proposed long-term monitoring locations.

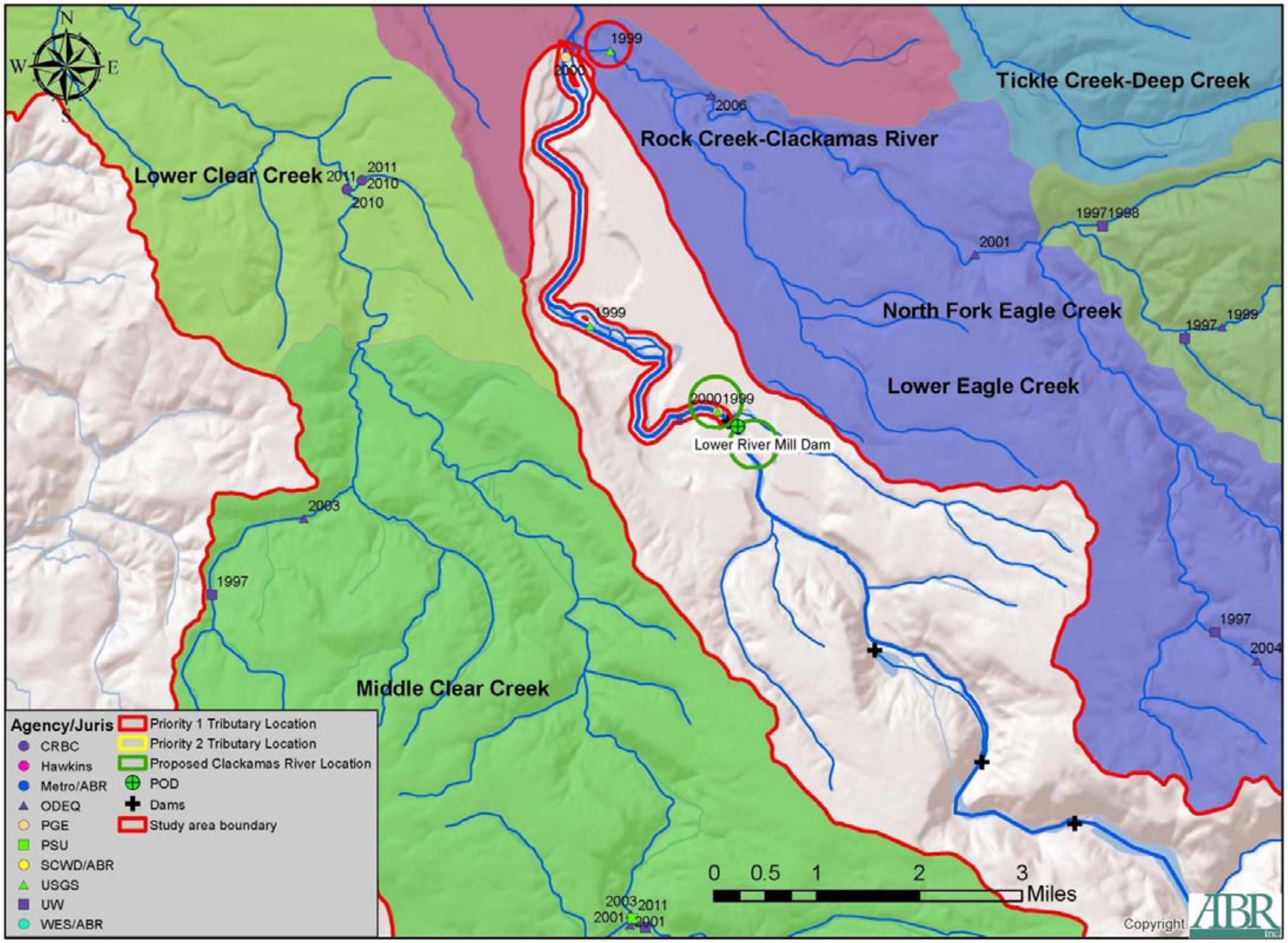

Figure 5. Two graphs of macroinvertebrate multimetric scores versus time for illustrating the potential effect of sampling frequency on the apparent relationship between scores and time. In the upper graph, annual scores reveal the lack of any strong trend, while samples collected less frequently run the risk of indicating a significant trend owing to inherent natural variability not fully represented by the less frequent sampling.