Interagency Regional Monitoring

Northwest Forest Plan

Aquatic and Riparian Effectiveness Monitoring Program

2002 Annual Report

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A copy of this report is also available on our Watershed Monitoring Website:
http://www.reo.gov/monitoring/watershed/

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

SUMMARY

The Aquatic and Riparian Effectiveness Monitoring Program (AREMP) was implemented during 2002 in 24 6th-field watersheds. A data quality assurance/quality control program was implemented and provided feedback on how to improve sampling efforts. Two test projects were also conducted to: 1) compare sampling data resulting from different agency protocols, and 2) resample the Glade Creek watershed, which burned after the 2000 sampling season, to determine whether our sampling methodology would be adequate to detect changes. Efforts to develop a state-federal monitoring partnership also continued.

AREMP is the pilot program for implementation of a quality system management plan across all of the Northwest Forest Plan monitoring programs. Two components were added to the data quality assurance program: field audits and exit surveys. Changes have been made to the crew-training program based on results of the field audits and exit surveys.

Based on the protocol test, a set of core indicators were identified that will be sampled by all monitoring programs. In addition, two of the monitoring programs (AREMP and the PacFish/InFish program – also known as PIBO) have adjusted protocols so that the programs use the same protocol for these core attributes.

In Glade Creek, we detected significant changes is fine sediment, pool frequency, log jams, and bank failures following the fire. Although a sample site of one is not adequate to assess our ability to detect change following disturbance, we are hopeful that the results of this watershed are representative of our ability to detect change.

A decision support model and attribute evaluation criteria are currently undergoing peer review. A series of workshops will be conducted in spring and summer of 2003, during which experts will refine the model and attribute evaluation criteria to apply to local conditions. The model structure, attribute evaluation criteria, and results will be shared with local managers when the peer review process is complete.

INTRODUCTION

Background

The Northwest Forest Plan (NWFP; hereafter referred to as “the Plan”) was approved in 1994. The Plan includes an Aquatic Conservation Strategy that requires the protection, rehabilitation, and monitoring of aquatic ecosystems under the Plan’s jurisdiction (USDA-USDI 1994). The Aquatic and Riparian Effectiveness Monitoring Program (AREMP or the monitoring plan) was developed to fulfill these monitoring requirements. The objectives of the monitoring plan include assessment of the condition of aquatic, riparian, and upslope ecosystems at the watershed scale; development of ecosystem management decision support models to refine attribute interpretation; development of predictive models to improve the use of monitoring data; providing information for adaptive management by analyzing trends in watershed condition and identifying elements that result in poor watershed condition; and providing a framework for adaptive monitoring at the regional scale (Reeves et al. 2001). Monitoring is conducted at the subwatershed scale (USGS 6th-field hydrologic unit code). These subwatersheds (hereafter referred to as “watersheds”) are approximately 10,000-40,000 acres in size.

Collection of field data began summer 2000 in four watersheds. The goal of the 2000 sampling was to test sampling protocols and determine the funding level and crew structure needed to implement the monitoring plan. A pilot project was conducted in 2001 in 16 watersheds to refine sampling protocols and to answer other questions related to implementing the monitoring plan. Full implementation of the monitoring plan began in 2002, although the number of sampled watersheds sampled was limited to 24 because of funding. The purpose of this report is to provide an overview of monitoring efforts in 2002.

Program Monitoring Objectives

Twenty-four watersheds spread throughout the Plan area were sampled during 2002 (Figure 1, Table 1). The objectives of the 2002 program included:

- Coordinating efforts to standardize federal watershed monitoring efforts within the Pacific Northwest.
- Evaluating whether our sampling efforts could detect a change after a large-scale disturbance occurred in a watershed.
- Implementing a data quality assurance/quality control program.

A complete discussion of each of these objectives is provided in subsequent sections. Included is a brief introduction, methods, and the results of each project. The Lessons Learned section contains a discussion of problems encountered during the 2002 field season and staffing changes that occurred. The Future Direction section provides refined estimates of the budget and personnel required to accomplish the tasks assigned to the module and the effort underway to coordinate the monitoring plan with other monitoring programs conducted by state and federal agencies in the Plan area.

FIELD EFFORTS

2002 Watershed Sampling

Two hundred fifty watersheds were selected for monitoring the Northwest Forest Plan (Figure 1). These watersheds were selected at random using generalized random stratified tessellation survey design, which guarantees a spatially balanced sample. Watersheds must contain a minimum of 25 % federal ownership (USDA Forest Service, USDI Bureau of Land Management [BLM], or USDI National Park Service) along the total length of the stream (1:100,000 National Hydrography Dataset stream layer) to be considered for sampling in the monitoring plan.

Of the 250 watersheds, 24 were sampled during the 2002 field season. To allow for temporal differences in stream flow across the Plan area and to minimize the impact of a drought occurring throughout the Pacific Northwest, crews sampled all watersheds in California, then Oregon, and finished the field season in Washington. Within each state, watersheds were sampled in random order by a randomly assigned crew.

Within each watershed, sample sites were randomly selected using the same procedure used to select watersheds. Crews sampled as many sites as possible during the sample period, six on average. A single crew conducted all sampling within individual watersheds. Crews collected a variety of data on the physical, biological, and chemical characteristics of streams (Table 2). A synopsis of the data collection methods is available online at: http://www.reo.gov/monitoring/watershed.

Standardizing Protocols

Introduction- Four large-scale watershed monitoring programs run by federal agencies are active in the Pacific Northwest, including AREMP, the Environmental Protection Agency’s Environmental Monitoring and Assessment Program (EMAP), the USDA Forest Service’s monitoring for the

Pacfish/Infish Biological Opinion (PIBO), and USDA Forest Service's Region 6 stream inventory. Although these programs differ in their objectives, they sample many of the same physical stream attributes. An effort is under way to standardize the sampling protocols used by these programs (particularly PIBO and AREMP) to facilitate data sharing. Toward that end, each program sampled the same stream reaches to determine whether the data collected by the different programs were comparable. The test was a part of a larger test conducted to examine reach-scale metrics that will be incorporated into the Aquatic Ecological Unit Inventories protocol. The specific objectives of the test include:

- Determine whether data collected by different programs were comparable.
- Compare consistency among observers using the same protocol.
- Determine which protocol methods most precisely measures each physical stream attribute.
- Integrate the most precise physical attribute sampling methods into a sampling design that will most efficiently detect change in streams due to management.

Based on the test results, certain attributes were defined as "core" (the attribute will be measured by each program) and a sampling protocol was recommended. Final decisions were posted on our website: http://www.reo.gov/monitoring/reports.htm#watershed.

Methods- Each program used independent crews to sample six different creeks, three on the Mt. Hood National Forest in Oregon and three on the Payette National Forest in Idaho. Three crews from each program sampled each creek. Crews from AREMP and PIBO sampled in both Idaho and Oregon. EMAP and USDA Forest Service Region 6 sampled Oregon streams only. Crews from the Oregon Department of Environmental Quality used the EMAP protocol in the Oregon streams, and crews from the Idaho Department of Environmental Quality used the EMAP protocol in the Idaho streams.

Crews were trained by their respective program using their protocols. A brief summary of the sampling protocols used by each program is provided in (Appendix A). A more comprehensive document is located on line at: www.reo.gov/monitoring/watershed/docs/Attributesformonitoringcomparison_Master_Table.html.

Several methods were used to examine the precision of the sampling. First, we determined whether the different protocols produced different results, then we examined the variance associated with each protocols. To determine whether the results of each program were different, we used analysis of variance (ANOVA) to examine the differences between the means of each attribute for each program. For this analysis, the protocol used was considered the independent factor and the response variable was the dependent factor. Response variables considered in this analysis include mean bankfull width, gradient, substrate D_{50}, percent fines, and percent pools. The ANOVA was conducted on Oregon and Idaho streams for AREMP, EMPA, and PIBO.

An examination of variance associated with the sampling data can be used as measurement of precision. Variance associated with field sampling can come from a variety of sources including natural variance associated with space and time, sampling error, and observer bias. The variance associated within each of the sources is positively related to the magnitude of the difference between measurements. For example, if every crew within a program measured percent gradient of 1.6 in stream A and 2.5 in stream B, then between-stream variance would be high and between-crew variance would be low. As the difference between measurements increases, so does the associated variance. The variance analysis for this test was composed of two parts: 1) partition of variance across programs for each response variable; and 2) calculation of coefficients of variation (CV) and signal to noise ratios (S: N). CVs were calculated for each program based on the Oregon streams. Signal to noise ratios were calculated for AREMP, EMAP, and PIBO using data from the Oregon and Idaho streams. Heath Whitacre, Department of Aquatic, Watershed, and Earth Resources, Utah State University, Logan, UT provided CV data for all attributes.

The variance partition across programs was conducted to determine how much of the variance within attribute measurements could be accounted for by the protocol that was used. This analysis was conducted only for AREMP, EMAP, and PIBO. For this exercise we examined five sources of variance:

1. Region – the difference between the creeks in Oregon and Idaho.
2. Creek – the difference between the creeks sampled within each region.
3. Protocol – the difference between observations within each creek that result from the use of different protocols.
4. Crew – the variance associated with crew bias and observer or measurement error.

5. Residual – the portion of the total variance that was not accounted for by the other sources.

The equation used for the analysis is as follows:

Total variance = Region + Creek (Region) + Protocol (Creek) + Crew (Protocol) + ResidualTerms in parentheses indicate nested terms. For example "Creek (Region)" indicates that the Creek term was nested within the Region term. This term was nested because three creeks were sampled in each region (Oregon and Idaho).

Coefficient of variation (CV) and signal to noise ratios (S: N) were calculated for each response variable within programs. CV is calculated by dividing the standard deviation of replicates (here, repeat visits) by the grand mean. Lower CVs indicate higher levels of precision.

S: N is the variance that can be associated with space and time (here Region and Creek) divided by the sum of crew and residual error. The equation used was:

$$S{:}N = \frac{\text{Region} + \text{Creek}}{\text{Crew} + \text{Residual}}$$

For this analysis, the variance for each response variable was partitioned within each program. The equation used was similar to the across programs analysis, except that the protocol variance term was dropped:

Total Variance = Region + Creek (Region) + Crew (Creek) + Residual.

Since only AREMP and PIBO sampled in both states during the protocol test, only these two groups will have variance associated with region.

High S: N ratios (usually ≥ 7) indicate we are able to detect differences between streams using the metric. If changes in a stream due to disturbance are similar in type and magnitude to differences among streams within a region, then S: N is a useful predictor of the metric's potential for discerning trends or changes in habitat condition (Kaufmann et al. 1999).

Results and Discussion-Significant differences between protocols were detected for percent pools, substrate D_{50}, and mean bankfull width (Figure 2). Overall, PIBO measured higher percent pools and substrate D_{50} than the other programs. These differences can be attributed to the PIBO's protocol:

their definition of pools was different than that used by the other protocols (Appendix A). In addition, PIBO measures pebbles for the D_{50} calculation only in riffles, whereas AREMP measures pebbles on transects evenly – spaced throughout the sampling reach, regardless of habitat. Because AREMP measures pebbles in both depositional and erosional habitats, the D_{50} should be lower than that measured by PIBO. EMAP was not included in the analysis of D_{50} because they bin their pebble sizes rather than making actual measurements. Consequently their D_{50} calculation is not comparable to that of AREMP and PIBO. In the variance partition analysis among programs, over 60 % of variance for percent pools and substrate D_{50} could be attributed to the protocol used (Figure 3).

AREMP had consistently higher mean bankfull widths relative to the other programs (Figure 2). AREMP measures bankfull width at evenly-spaced transects within the reach (n=6 in constrained reaches, n=11 in nonconstrained reaches) whereas PIBO measures at the widest point in the first four riffles. Protocol used accounted for only 4 % of the variance in bankfull width (Figure 3), and made no contribution to the remaining variables.

Perhaps more important than the programs producing different results is determining whether the differences between program results are predictable. To answer this question, we conducted regression analyses of those attributes that were significantly different among programs. Strong correlations were found for bankfull width and for substrate D_{50}, but not percent pools (Figure 4).

The final step in the analysis was to establish the core attributes and recommend protocols, based on the precision estimates associated with each program. The CVs and S: N calculations are presented in Table 3. Final recommendations were made in mid-April 2003, both PIBO and AREMP have adjusted their protocols accordingly.

Included on the list of core attributes are slope, bankfull width and depth, entrenchment ratio, substrate D_{50}, percent fines, pool frequency, and wood frequency. To make the PIBO and AREMP data more comparable, PIBO has increased its minimum site length to 150 m. AREMP will change its definition of pool to that of PIBO and measure gradient twice to increase the precision of the estimate.

Trend Detection

The Glade Creek watershed was sampled in October 2000. Glade Creek is a tributary of the Little Applegate River on the Rogue River National Forest in Oregon. Approximately 43 % of the 8,700-acre watershed was burned during the Quartz fire in August 2001 (Figure 5). We returned to sample the watershed in October 2002 to determine whether our sampling techniques were adequate to detect impacts from the fire. Fortuitously, sample sites were located above, within, and below the fire (Figure 5).

Two different surveys were conducted in Glade Creek, intensive surveys in the sites marked in Figure 5, and extensive surveys that began at the lowest point in the watershed on federal land and extended to the headwaters of the watershed. In the intensive surveys, data were collected on the attributes described in Table 2. The same protocol was used in both years. In the extensive survey, we documented (with digital photographs and GPS) features such as log jams, pools > 1m deep, and bank failures.

Analyses of the data were designed to examine differences in the attributes due to the presence of the fire and the intensity of the fire. Differences between individual attributes in 2000 and 2002 were examined using a two-tailed t-test. The null hypothesis was that the difference between attributes in 2000 and 2002 would be equal to 0. To examine the effects of the magnitude of the fire on individual attributes, we conducted a regression analysis with magnitude of fire (low, mid, high intensity) as the independent factor and individual attributes as the dependent factor. We also examined the impacts of the fire in downstream sites relative to the upstream sites, to determine whether the impacts of the fire were consistent across the longitudinal gradient in the watershed.

In the intensive surveys, significant fire effects were detected on fine substrates and pool frequency. Fine substrates increased in 2002 compared with 2000 (Figure 6, top). Fine substrates are defined as those < 2 mm along the intermediate axis. The fines data reported here is the number of times in each site that fine substrates were measured in the 121-particle pebble count. Pool frequency decreased following the fire, by nearly one half (Figure 6, bottom).

More fines were detected in 2002 in the lower reaches in the watershed than in the upper reaches of the watershed (Figure 7). Although more fines increased in 2002 in seven of the ten sites, the proportionately more fines were detected in the three lowest stream reaches. Longitudinal patterns were not detected for any of the other indicators.

The magnitude of the fire had an influence only on residual pool depth. Over all of the sites, residual pool depth was not significantly different in 2002 from 2000. However residual pool depth decreased in each of the sites in the mid intensity fire zone (Figure 8). Relationships with magnitude of fire were not detected for any other attributes.

In the extensive survey, significant differences were detected for number of deep pools (> 1 m residual depth), number of log jams, and number of bank failures. Fewer deep pools were measured in 2002 than 2000 (Figure 9, top). The number of log jams more than doubled in 2002 (Figure 9, center). The number of bank failures increased from 22 in 2000 to 72 in 2002 (Figure 9, bottom).

In assessing our ability to detect change following a disturbance such as the fire in Glade Creek, we first ask what changes we expect to occur. It is unlikely that stream morphological attributes such as bankfull width and entrenchment ratios will change due to the fire in the course of a year. Given this expectation, the change in pool frequency is surprising. Those attributes that we would expect to change include fine sediments and wood, both of which we detected changes in. The increase in fines is likely due to the high number bank failures. Much of the new wood present in the stream appears to be related to fire suppression activities. Many large trees were felled into the stream channel.

We recognize that a single watershed is not adequate to determine our ability to detect trends across the Northwest Forest Plan area, however we are hopeful that our ability to detect change in this watershed is indicative of our abilities overall. We will continue to look for opportunities to examine our ability to detect trends in watershed condition.

QUALITY ASSURANCE PROGRAM

Introduction

Development of the data quality assurance (QA) program continued during 2002. Several new components were added (both field and non-field) to the program implemented during the 2001 field season (Gallo et al. 2001). The added components are part of the Quality System Management Plan (QSMP; Palmer in preparation), which will be finalized in 2003.

The goal of the QSMP is to ensure that all data collected are scientifically sound and of known quality. AREMP was selected as the pilot program for implementing the QSMP across all of the Northwest Forest Plan monitoring programs. The QSMP should be implemented across all of these programs by 2005.

Field audits and crew exit surveys were added to our previous QA efforts (remeasuring sites with an independent crew, also known as “blind checks”). Field audits were conducted on site by the training cadre or crew supervisors (non-crew members). The audits were designed to determine whether the crews were following safety guidelines and sampling protocols. Field audits covered all aspects of sampling, including identification of fish and amphibians, correct measurement of attributes such as pebbles and wood, and proper calibration of electronic equipment.

Exit surveys were designed as self rating questionnaires that addressed four general topics: 1) how well did the training prepare you for the field work; 2) how well did you understand the concepts underlying the sampling; 3) how clear was the field protocol; and 4) what was your ability to do the field work. Exit surveys were given to all departing summer employees. The results of returned exit surveys were summarized and adjustments were made as necessary to field protocols and training.

In 2003, AREMP will add the following as part of the quality assurance program:

- Formalized lesson plans to the field training
- A standard operating procedure for the field crews
- A revised field protocol based comments from last year’s field crew members
- More intensive field audits
- A complete equipment and crew tracking system that tracks individuals and individual pieces of equipment to particular data
- A set of standard procedures designed to detect outliers and possible errant data points
- A document that outlines AREMP’s compliance with the QSMP

Analyses of the quality assurance data were conducted to determine the repeatability of the sample data. Variance decomposition was conducted to highlight attributes for which crew error had greater impact on the variance structure than the environmental variation. An evaluation of the representation of the time two surveys as a component of the initial surveys was also conducted to ensure that conclusions drawn from the time one and time two plots and variance decomposition were applicable to the rest of the sites in the watersheds. A forth coming report (Palmer and Moyer, in preparation) will detail the methods and results of the Quality Assessment program with particular emphasis on the field data.

Methods

The blind check component of the field effort was conducted as in 2001 with one difference: a single crew was designated as the quality control crew instead of a rotating randomly selected crew. This crew conducted all resurveys throughout the summer, and did not complete any of the original sampling. During the resample, data were collected for the same suite of attributes (Table 2) using the same collection methods as the original intensive survey. Each watershed was resampled within two - four weeks after the original sample.

Comparisons were made between the initial survey and the second survey using regression analysis. If the two crews measured the same attribute at the same location, they should generate the same value for the attribute. Consequently, if the results from crew 1 were graphed as a function of crew 2's results, the data points should fall on the 1:1 line. Regression lines were fit to the 2001 and 2002 data separately. Tests were then conducted to determine if the slope of the regression line was significantly different than one (H_o:β=1, H_a:$\beta \neq 1$, α=0.05), which would suggest that one set of values was substantially different than the second. Simple linear correlations were also generated. These graphs can be viewed in the Power Point presentation titled QAQC_Results_CDM.ppt at the following website: http://www.reo.gov/monitoring/reports.htm - watershed.

Variance decomposition (or partition) for the different attributes (see the Standardizing Protocols section for a description of the methods) was conducted using the following model:

$$Attribute = Creek + Site(Creek) + Visit(Site) + \varepsilon$$

where *Creek* represents the variance between watersheds, *Site(Creek)* is variance associated with sites within each creek, and *Visit(Site)* is the variance associated with the difference between visits. The last term (ε) is the residual error term, which includes all variance not accounted for by the other terms, including the difference in the environment between sample time one and time two.

The distribution of the attribute values from the time two survey was compared to the distribution of the attribute values from time one using Quantile-Quantile (QQ) Plots (Cleveland 1993). The distribution of the time one surveys included all sites in the watershed. The distribution of time two surveys includes from only the second survey at those sites in which two surveys were conducted. These graphs can be viewed in the Power Point presentation titled QAQC_Results_CDM.ppt at the following website: http://www.reo.gov/monitoring/reports.htm - watershed.

Results and Discussion

During the 2001 field season, AREMP resurveyed 32 sites in 16 watersheds (34% of the total sites surveyed). During the 2002 field season, 41 sites in 23 watersheds (33% of the total sites surveyed) were resurveyed.

Plots of the initial survey and the secondary survey revealed several interesting points (Table 4):

1. Typically, the relationship between the two surveys was stronger – as indicated by the simple linear correlation coefficient - in 2001 than 2002.
2. Slopes that were significantly different from one (reject Ho:β=1 in favor of Ha:$\beta \neq$1) often occurred in the 2002 dataset exclusively with one exception or they occurred in both years' data.
3. The 2002 quality control crew often had lower attribute values than the initial survey indicating a more conservative survey (see graphs referenced above).
4. For the dissolved oxygen (DO) data collected during 2002, the concentration ranges from 4 to 16 mg/l for the initial survey crew and with one exception from 4 to 10 mg/l for the second crew (see graphs referenced above).

The primary difference between the two years is the randomly assigned quality control crew in 2001 verses the fixed quality control crew in 2002. This difference probably accounts for the stronger relationships in the 2001 dataset. In the 2002 dataset, the quality control crew often had lower attribute values. During the 2001 field season, the quality control crew was responsible for surveying six sites (two sites in three watersheds) during each two-week work period. In 2002, the crew had to resurvey eight sites (two sites in four watersheds) in the same time period. This increase in productivity may be responsible for the more conservative attribute values. As a consequence of spending less time at each site, the second crew may have been more likely to determine, for example, that an individual piece of wood did not meet the minimum size criteria and therefore was not part of the survey. Finally, the 2002 quality control crew used one set of water chemistry meters throughout the season. The apparent "ceiling" in values is probably due to differences in equipment.

The variance decomposition results show that residual (or unexplained) error increased considerably from 2001 to 2002 for almost all attributes. Interpretations of these results are confounded by shifts in the total variation accounted for by the environment (the variation between both creeks and sites within a creek). Depending on the attribute, this shift can be attributed to changes in the protocol between years, changes in the training curriculum, and changes in equipment.

The QQ plots indicate that, for the most part, the data collected by the second crew is representative of the data population as a whole. There were a few instances in which the QQ plots revealed an extreme value. These values could either be data errors or at the extremes of the distribution of attribute values. Efforts are underway to seek out these values and attempt to eliminate the former option. Because these values are representative, interpretation of the quality control crew results can be applied to the rest of the sites, i.e., the results are not specific to a particular site or watershed.

SPECIAL PROJECTS

Redundancy Analysis

An analysis to examine the overlap of the in-channel attributes in describing the total variance of the system was conducted. Termed “redundancy analysis”, searching out strong correlations between attributes can allow for the reduction of attributes and/or development of models that can be used in a predictive sense. The overall goal was to determine whether the data collected for different attributes were measuring the same component of the overall variation.

The analysis was a two-step process. First, simple linear correlations between all in-channel attributes were generated and examined for those attributes that were highly correlated. Second, a Principle Components Analysis (PCA) was conduced to establish overlaps (or principle components) between attributes.

Results indicate that there is little correlation beyond what was expected, e.g., average bankfull width and stream length (the former is used to determine the later). The PCA results were similar with the first two components (or factors) being loaded by primarily one attribute. The first component consisted almost entirely of the D_{50} while the second component was comprised of stream length and conductivity (however, conductivity was only moderately correlated with the component, r=0.30).

Due to the lack of an obvious relationship between attributes, we concluded that there was little or no redundancy in the attributes. The lack of redundancy suggests that none of the attributes should be dropped from the sampling effort. The lack of redundancy also points to a quality design in the selection of attributes. Additional details about the redundancy analysis are available at http://www.reo.gov/monitoring/reports.htm#watershed under the "Integrating National Forest large-scale monitoring efforts" presentations and information section.

Gradient Analysis

In support of the both the November 2002 Large-Scale Monitoring Workshop and the protocol standardization, a simple analysis was conducted to determine whether gradient had an impact on protocol execution and if there was evidence to support stratification of sample reaches within a watershed by gradient. If possible, one non-random site was sampled (located on the lowest-most nonconstrained portion of the watershed on federal land) in each of the 24 watersheds sampled during 2002. Sixteen of the 24 watersheds did not contain nonconstrained sections; consequently, only eight sample points were used in the analysis. Watersheds that had "lowest-most" nonconstrained reaches (hereafter referred to as lower reaches) in them were examined for differences in physical, chemical, and biological attributes between the lower reach and the pooled values for the remaining reaches.

Sites and subsequent attributes, were split into gradient classes of 0-2, ≥2 and <4, ≥4 and <10, and ≥10 % gradient. The total variation for each attribute by gradient subset was decomposed into:

$$Attribute = Creek + Site\,(\,Creek\,) + \varepsilon$$

where the *Creek* term represents the variation between watersheds, the *Site(Creek)* term is the site nested within creek, and ε is the residual error term. These components were then used to calculate the signal to noise ratio:

$$S:N = \frac{Creek + Site}{Error}$$

See the discussion under the Standardizing Protocols section for more details.

To compare the lower reaches with the values from the remaining reaches, paired sample t-tests were used for physical and chemical attributes. Aquatic amphibians and fish were examined by simply comparing the number of species captured in each of the two types of sites as well as the number of predicted species. The predicted number of species was estimated using EstimateS software (Colwell 1997).

The gradient breakdown of the AREMP sites indicates that approximately half of the sites surveyed to date are at gradients of less than 4 %, and 85 % of the sites are at gradients of less than 10 %. Examining the variance components in detail suggest that for some attribute/gradient combinations, gradient does have an impact on implementation of the field protocols (). Further, the range of attribute values was approximately the same in each gradient class, which suggests that no advantage will be gained by stratifying sites by gradient class.

This analysis revealed distinct differences between the lower sites then the remaining sites in each watershed (Table 5). Physically, the lower reaches are, on average, wider, lower gradient, have smaller substrate, and lower pool frequencies. Chemically, lower reaches have lower concentration of dissolved oxygen relative to the random sites. Biologically, the lower reaches have fewer species present than the pooled upstream reaches and fewer species than the predicted number (Table 6). The pooled upstream reaches had either fewer or the same number of predicted species.

DECISION SUPPORT MODELING EFFORT

A decision support model and attribute evaluation criteria were developed in 2001 to conduct assessments of watershed condition. Provincial-level teams of experts have been assembled and they are currently in the process of refining the models and conducting a rigorous peer review. Members of the peer review teams include agency aquatic ecologists, fishery biologists, and hydrologists that have good on-the-ground knowledge of watersheds in their areas. Each team will meet for a two-three day workshop, during which the team will thoroughly examine the model structure and attribute evaluation criteria. The model developed in the workshop will be run on data collected in the area, and the teams will evaluate whether the model results are consistent with their professional opinion of watershed condition, and then refine the model as necessary. Model results will be validated on an independent set of watersheds. The model structure, evaluation criteria, and results will be distributed to local managers when the review is complete.

Following the workshops, an analysis of the model will be conducted to determine how sensitive the model is to changes in individual attributes. We expect that the importance of individual attributes in determining watershed condition will change across provinces. The sensitivity analysis should determine which attributes tend to influence the overall watershed condition score, as well as the magnitude of change required in the attributes for trend detection. In short, we need to ensure that the model can detect changes of the magnitude that management activities are expected to produce.

LESSONS LEARNED

Problems Encountered During 2002

Several issues arose during the 2002 field season that had not been previously encountered. Those issues along with the solutions to the problems are outlined below. Solutions to these issues are paraphrased (in *italics*) from conversations with Phil Larsen (EPA-Corvallis) with advice input from Tony Olsen (EPA – Corvallis).

Fire-Forest fires are particularly problematic because they are unpredictable and do not necessarily occur at regular intervals. Consequently, crews can be impacted during the middle of a field stint. The two primary impacts to the field season were either the complete inaccessibility to a watershed or having to withdraw from a watershed during the field sampling efforts.

No sampling – Last year, AREMP was unable to sample a watershed due to fire danger. Because of the fire danger, the watershed was dropped from the survey list (coded as a non-response); however, the watershed is expected to be accessible in every aspect in 2003.

Questions:

1. Should this watershed be sample in 2003?

   This watershed should be coded as a non-response and an attempted resurvey should take place in five years on the normal resurvey cycle.

Partial Sampling – Last year, AREMP was able to sample two sites prior to being evacuated due to a forest fire. Again, this watershed is expected to be completely accessible in 2003.

Questions:

1. Should this watershed be sampled in 2003?

   This watershed should be coded as a non-response and an attempted resurvey should take place in five years on the normal resurvey cycle.

2. Should we drop the 2002 information and try to build a more complete dataset from just 2003 surveys?

   No, use the 2002 data.

3. Should we keep the 2002 data and collect additional information in 2003 to make a more complete dataset?

   No. Use the data collected in 2002 from both sites.

4. If so, how should this watershed be treated with respect to the resurveys? (No quality assessment resurveys were conducted in this watershed.)

   Revisit both sites in 2003 for the variance estimation process.

Dry Watersheds – AREMP encountered a watershed in which the stream was dry. According to the local unit fish biologist, this particular stream is an excellent steelhead producer (evidently fry move out of the system before it goes dry). This watershed was coded as a non-response due to the timing of the surveys.

Questions:

1. Should this watershed be sampled in the 2003 field season and AREMP makes the effort to sample it as early in the field season as possible?

   This watershed should be coded as a non-response and an attempted resurvey should take place in five years on the normal resurvey cycle.

   a. If so, how should this watershed be treated with respect to the resurveys (if, for example, it is in the first five watersheds and would be selected for resurvey)?

      No revisits, as they will add nothing to variance estimation.

Site dry up between surveys – AREMP encountered an instance where a site went dry after the initial survey and before the QA survey took place. (Only one site in the watershed was surveyed a second time.)

Questions:

1. Is it legitimate to randomly select a different site (a replacement) so that two sites are resurveyed within the watershed?

   Code the dry site as a non-response (for QA) and select the next random site from the sequential list of sites initially surveyed.

2. If so, how should this watershed be treated with respect to the resurveys (if, for example, it is in the first five watersheds and would be selected for resurvey)?

   Treat this watershed as you would other with the revisits.

Feasibility – As a test case, AREMP surveyed a remote watershed that required the use of a horse packer, remote camping, and a lot of hiking time. Because of events beyond our control, AREMP was unable to conduct QA surveys in the watershed.

Question:

1. How should this watershed be treated with respect to the resurveys?

   In the future, in situations of this nature resurveys can be conducted at the time of the initial survey.

Staffing Changes

We tried using a different crew staffing structure during 2002 in an attempt to improve field sampling efficiency. We changed from having a single five-person habitat/biology crew for each watershed to a three-person habitat and a two-person biology crew. Each biological crew worked with two habitat crews. We discovered that there was no gain in efficiency over having a single five-person habitat/biology crew, and the new staffing structure reduced our flexibility for having people assist with other tasks as needed. We will return to using a single five-person crew to sample each watershed in 2003, however individuals will be assigned to either the habitat or biological component of the survey.

Based on our 2000 and 2001 surveys we added another crewmember (the “block leader”) to conduct reconnaissance of the watersheds before field crews arrive on site, and assist in crew supervision in the field. Scouting watersheds involves, but is not limited to, tasks such as finding major access roads, camp sites, creek access points, determining which sample sites are suitable for survey, and placement of water temperature probes. The block leaders were also responsible for general crew management tasks. Those tasks included checking the data for quality assurance, serving as the conduit for equipment repair and replacement, and serving as another check to ensure protocols are correctly followed. The block leader positions proved to be invaluable to ensuring a well coordinated field effort, although we found they often became stretched to thin because of all their duties. We intend to continue the block leader positions in 2003 (placing one block leader with every two field crews), along with hiring a two-person crew focused on site reconnaissance throughout the summer.

FUTURE DIRECTION

Budget Update

The anticipated costs for future watershed surveys based on “lessons learned” during the 2002 field season, are presented in Table 7. For full implementation of the monitoring plan (50 watersheds), it will cost $35,240 to sample each watershed, or $7,033 per sample site, assuming that an average of 6 sites continues to be sampled in each watershed. These figures were derived from taking our total budget and dividing by the number of watersheds sampled, therefore the figures include overhead and other non-field related costs.

State-Federal Coordination

Cooperative monitoring efforts between state and federal agencies are a natural extension of the monitoring plan as we look for ways to reduce costs and gain a better understanding of the interaction of federal, state, and private land watershed management actions within the NWFP area. Monitoring plan personnel began hosting monthly meetings in November 2001 with state agency representatives from Washington, Oregon, and California to explore how to develop a monitoring partnership. The following is a summary progress made during 2002.

Action items in 2002 for the state-federal partnership team include:

- Create an integrated land use/land cover/roads database.
    - Significant progress was made on a cooperative effort between state and federal agencies that will allow – for the first time – everyone to use the same data to describe selected watershed GIS attributes. The sixth field watershed layer is on version 1.3 (third version) and will soon be available for update in an online library. Some other layers that are close to being finished are streams, vegetation (interpreted from Landsat TM images), federal ownership, and land use areas. A road layer is also being developed for all state, federal, and private lands.
- Develop options for selecting a common randomized sampling protocol that allows the greatest inference across the landscape.

    - General agreement was reached that using a Generalized Random Tesselation Sampling strategy is the best way to ensure uniform, randomly distributed sample sites.
- Get the right people together to talk about data management/sharing.
    - A focus group of state and federal agency data managers met to share ideas on how to best manage and share data.
- Engage National Marine Fisheries Service, Northwest Power Planning Council, Bureau of Reclamation, and Bonneville Power Authority (BPA). Work towards consistent approach among states and within Columbia River Basin.
    - AREMP personnel began discussions with BPA and the Resource Monitoring Team (RMT) of the Federal Caucus (to explore the possibility of using the ongoing "AREMP state-federal monitoring partnership") to help meet the RMT's state-tribal coordination obligations.
- Identify opportunities to standardize the protocols currently being used by monitoring programs.
    - An overview of attributes and associated protocols used by 10 different state and federal monitoring efforts was compiled. The overview is available at: http://www.reo.gov/monitoring/reports.htm#watershed.
    - AREMP helped coordinate and hosted an "Integrating National Forest large-scale monitoring programs" workshop, which was attended by more than 60 state and federal specialists. Task teams were assigned to recommend a core set of standardized in-channel and biological attributes and protocols that both AREMP and PIBO would use. A riparian team was formed to identify how to standardize monitoring riparian areas; an upslope team is developing proposals for how to better monitor upslope processes. The papers presented at this workshop are available at: http://www.reo.gov/monitoring/reports.htm#watershed.

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TABLES

Table 1. Watersheds sampled in 2002 by the Aquatic and Riparian Effectiveness Monitoring Program (AREMP). Included is the state, county, physiographic province, the National Forest (NF), National Park (NP), or Bureau of Land Management (BLM) District that manages the watershed, the watershed name, and the major river system in which the watershed is located.

State	County	Province	Administrative Unit	Creek Name	Major River System
OR	Douglas	Klamath/Siskiyou	BLM-Medford	Galesville Creek	South Fork Umpqua River
OR	Coos	Klamath/Siskiyou	BLM-Medford	Upper West Fork Cow Creek	South Fork Umpqua River
OR	Coos	OR/WA Coast	BLM-Coos Bay	North Fork Coquille River	Coquille River
OR	Clackamas	West Cascades	BLM-Salem	Upper Molalla River	Willamette River
OR	Klamath	High Cascades	Crater Lake NP	East Fork Annie Creek	Klamath Lake
OR	Deschutes	High Cascades	Deschutes NF	Snow Creek	Deschutes River
OR	Klamath	High Cascades	Deschutes NF	Summit Creek	Crescent Lake
WA	Skamania	North Cascades	Gifford Pinchot NF	Big Lava Bed Frontal Creek	Little White Salmon River
WA	Lewis	West Cascades	Gifford Pinchot NF	Willame Creek	Cowlitz River
CA	Siskiyou	Klamath/Siskiyou	Klamath NF	South Fork Salmon River	Klamath River
CA	Glenn	Klamath/Siskiyou	Mendocino NF	Upper Black Butte River	Eel River
WA	Pierce	North Cascades	Mt Baker-Snoqualmie NF	Upper White River – Silver Cr	White River
OR	Clackamas	West Cascades	Mt. Hood NF	Still Creek	Sandy River
WA	Skagit	Western Cascades	North Cascades NP	Fisher Creek	Skagit River
WA	Jefferson	Olympic Peninsula	Olympic NF	Hamma Hamma River	Hamma Hamma River
OR	Josephine	West Cascades	Rogue River NF	Glade Creek	Little Applegate River
OR	Josephine	Klamath/Siskiyou	Rogue River NF	Steve Fork Carberry Creek	Applegate River
OR	Coos	Klamath/Siskiyou	Siskiyou NF	South Fork Coquille River	Coquille River
CA	Trinity	Klamath/Siskiyou	Six Rivers NF	North Fork Eel River	Eel River
CA	Del Norte	Klamath/Siskiyou	Six Rivers NF	Shelley Creek	Smith River
OR	Douglas	West Cascades	Umpqua NF	Dumont Creek	South Fork Umpqua River
WA	Cittias	High Cascades	Wenatchee NF	Swauk Creek	Yakima River
OR	Linn	High Cascades	Willamette NF	Upper Quartzville Creek	Santiam River
OR	Linn	West Cascades	Willamette NF	Sixes Creek	Santiam River

Table 2. Summary of methods used to collect data on Aquatic and Riparian Effectiveness Monitoring Program (AREMP) watershed condition attributes.

Attribute	Collection	Method
Physical Habitat		
Bankfull Width: depth	Calc.	= bankfull width / mean bankfull depth
Gradient	Calc.	= rise / run of the sample reach
Sinuosity	Calc.	= stream length / valley length
Entrenchment ratio	Calc.	= flood prone width / bankfull width
Substrate D_{50}	Field	Modified Wolman pebble count
Percent fines	Field	Klamath grid
Wood frequency	Field	Tally of wood in sample reach
Pool frequency	Field	Tally of pools in sample reach
Pool residual depth	Calc.	= Pool max depth - pool tail crest depth
Water Chemistry		
Total Kjeldahl nitrogen	Field	Water collected for lab determination
Total phosphorus	Field	Water collected for lab determination
Dissolved oxygen	Field	YSI 556 MPS meter
Conductivity	Field	YSI 556 MPS meter
pH	Field	YSI 556 MPS meter
Temperature	Field	Onset Optic Stowaway data logger
Biological Sampling		
Periphyton	Field	Removal from known substrate area
Macroinvertebrates	Field	Kicknet sampling in riffle habitats
Amphibians	Field	Electrofishing and timed stream bank searches
Fish	Field	Electrofishing

Table 3. Precision estimates for four monitoring/survey programs compared in a 2002 protocol test. Included is the coefficient of variation (CV), and the signal to noise (S: N) for each of the attributes considered. CV data were provided by Heath Whitacre, Department of Aquatic, Watershed, and Earth Resources, Utah State University, Logan, UT.

AREMP = Aquatic and Riparian Effectiveness Monitoring Program, EMAP = Environmental Protection Agency's Environmental Monitoring and Assessment Program, PIBO = the USDA Forest Service's monitoring for the Pacfish/Infish Biological Opinion, and FS R6 = USDA Forest Service's Region 6 stream inventory.

	Attribute	**AREMP**	**EMAP**	**FS R6**	**PIBO**
CV					
	Bankfull width	24	18	5	6
	Slope	22	16	-	7
	Percent fines	85	13	52	40
	D_{50}	16	59	18	24
	Wood Frequency	31	36	18	18
	Percent pools	63	42	24	18
S:N					
	Bankfull width	2.2	0.2		54.0
	Slope	7.0	1.3		53.0
	Percent fines	0.7	14.8		27.1
	D_{50}	5.1	-		5.4
	Percent pools	0.4	0.0		6.3

Table 4. Aquatic and Riparian Effectiveness Monitoring Program (AREMP) correlation coefficients and slope test information for the initial survey and the second survey for the quality control blind checks during 2002. The correlation coefficient, slope of the fitted regression line and the probability of the test for Ho:β=1, are represented by r, β, and probability, respectively.

Indicator	**2001 r**	**2002 r**	**2001 β, probability**	**2002 β, probability**
Site Length	0.98	0.93	1.03, 0.437	1.03, 0.697
Average Bankfull Width	0.99	0.97	1.19, 0.000	0.98, 0.665
Average Bankfull Depth	0.77	0.64	0.78, 0.077	0.56, 0.000
Average Bankfull Width:Depth	0.82	0.63	0.73, 0.009	0.61, 0.002
Gradient	0.95	0.99	1.00, 0.947	0.98, 0.416
Sinuosity	0.27	0.87	0.79, 0.690	0.84, 0.040
D50	0.82	0.89	0.14, 0.000	0.67, 0.000
D50 without bedrock	0.86	0.85	0.76, 0.008	0.83, 0.041
% Pool Tail Crest Fines	0.60	0.47	1.07, 0.802	0.54, 0.019
Pieces of wood	0.81	0.59	0.66, 0.002	0.35, 0.000
Number of Pools	0.24	0.03	0.30, 0.008	0.02, 0.000
Average Residual Pool Depth	0.72	0.39	0.91, 0.562	0.30, 0.000
Dissolved Oxygen	-0.07	0.06	-0.05, 0.000	0.07, 0.000
Conductivity	0.90	0.96	0.92, 0.330	1.15, 0.010
pH	0.61	0.38	0.74, 0.161	0.53, 0.038

Table 5. Aquatic and Riparian Effectiveness Monitoring Program (AREMP) attribute means and variances for the lowest non-constrained reach and the pooled remaining upper reach random sites during 2002. Attributes in italics were found to be significantly different at α=0.05.

	Lowest Non-Constrained Reach (n=8)		**Remaining Random Sites (n=38)**	
Attribute	**Mean**	**Variance**	**Mean**	**Variance**
Site Length	283.0	18952.6	203.5	3048.7
Bankfull Width	11.9	32.3	8.5	5.5
Bankfull Width:Depth	23.4	65.6	20.8	28.0
Gradient	1.2	0.4	5.6	11.7
Sinuosity	1.5	0.1	1.3	0.01
Percent Fines	19.6	240.2	11.3	70.8
D_{50}	22.2	433.4	59.8	1533.7
Pool Frequency	1.0	0.5	1.8	0.6
Wood Frequency	7.2	23.6	6.3	18.7
Dissolved Oxygen	8.2	6.6	9.5	2.8
pH	7.1	1.0	7.3	0.6
Conductivity	68.7	2199.2	66.5	1972.9

Table 6. Number of species captured in the two different reach types as well as the number of species predicted for each watershed sampled during the 2002 Aquatic and Riparian Effectiveness Monitoring Program (AREMP). “Lower reach” refers to the lowest-most nonconstrained reach in the watershed. “Pooled upper reaches” refers to the number of species captured in the randomly selected sample reaches.

Watershed Name	Lower Reach (n=6)	Pooled Upper Reaches (n=31)	Predicted # of Species (Pooled Upper Reaches)
Upper Cow Creek	5	7	7
Still Creek	4	6	7
Summit Creek	0	1	1
Hamma Hamma River	3	1	15
Swauk Creek	2	4	4
Silver Creek	2	4	6
	Average = 2.6	Average = 3.8	Average = 6.7

Table 7. Summary of the costs per watershed by three major categories of the Aquatic and Riparian Effectiveness Monitoring Program (AREMP). The Description column describes in general terms, the types of tasks that make up the area of operation. The next three columns give the cost per watershed for each of three scenarios, surveying 25, 30, and 50 watersheds, respectively. The cost per sample sites assumes an average of six sample sites in each watershed surveyed.

Categories	**Description**	**Cost per watershed @ 25 6th-field HUCS**	**Cost per watershed @ 30 6th-field HUCS**	**Cost per watershed @ 50 6th-field HUCs (full implementation)**
Program Coordination	Manage budget, purchases, and hiring personnel; communication and coordination with other agencies; presentations and reports.	$14,400	$12,000	$8,920
Watershed Sampling	Hiring, training, safety, travel, salaries for field crews; equipment purchasing, acquiring sampling permits, GIS support	$22,200	$22,600	$23,300
Decision Support Model	Refining evaluation curves and the decision support model structure; checking for errors, & archiving raw data; data analysis; and generating data summaries and preparing reports	$5,560	$5,000	$3,000
	Total Program Costs	$1,055,000	$1,202,000	$1,775,000
	Total/watershed	$42,200	$39,600	$35,240
	Total/sample site	$7,033	$6,678	$5,917

FIGURES

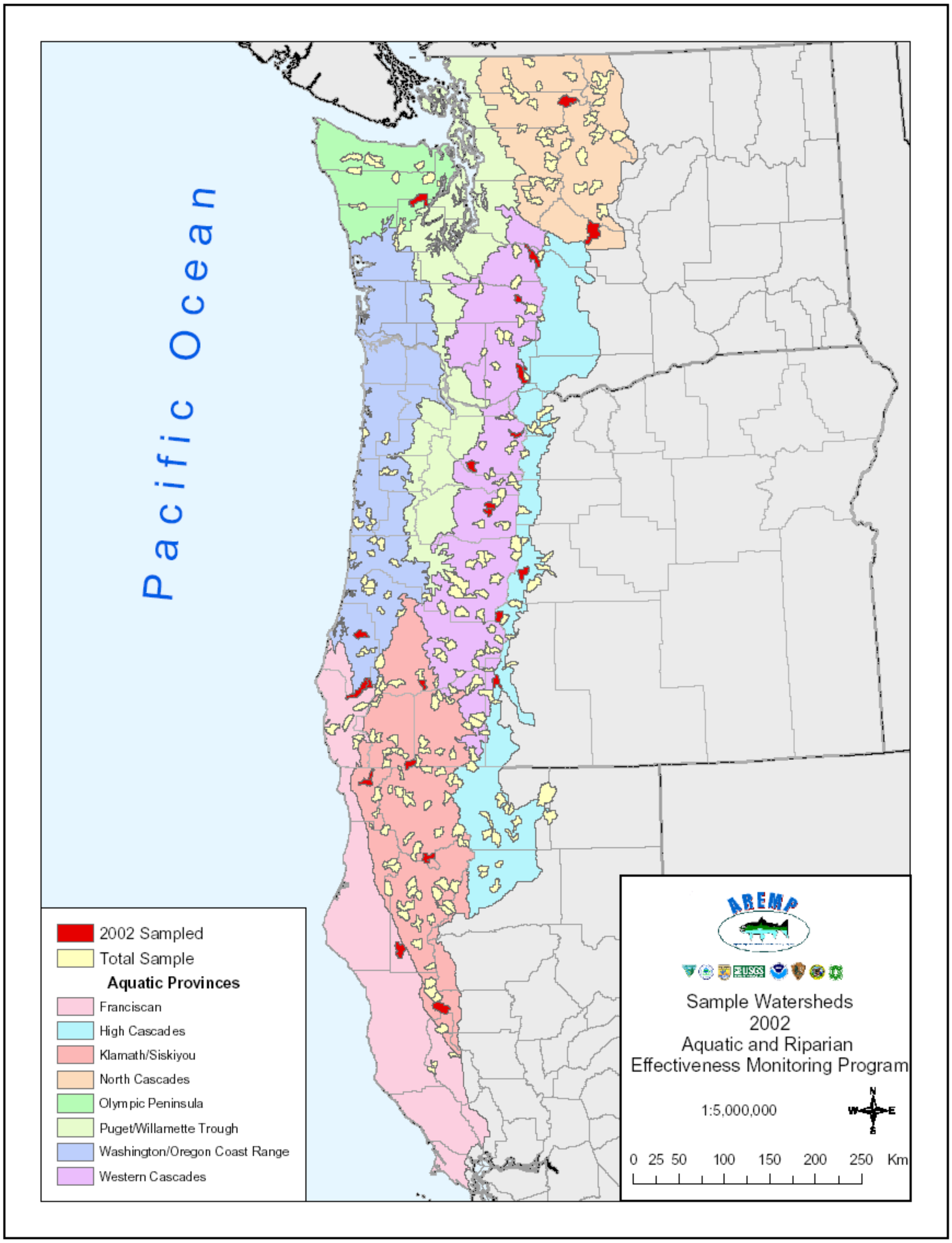

Figure 1. Map of the watersheds included in the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) sampling. Watersheds sampled during the 2002 field season are highlighted in red. The aquatic provinces of the Northwest Forest Plan are color coded in the background.

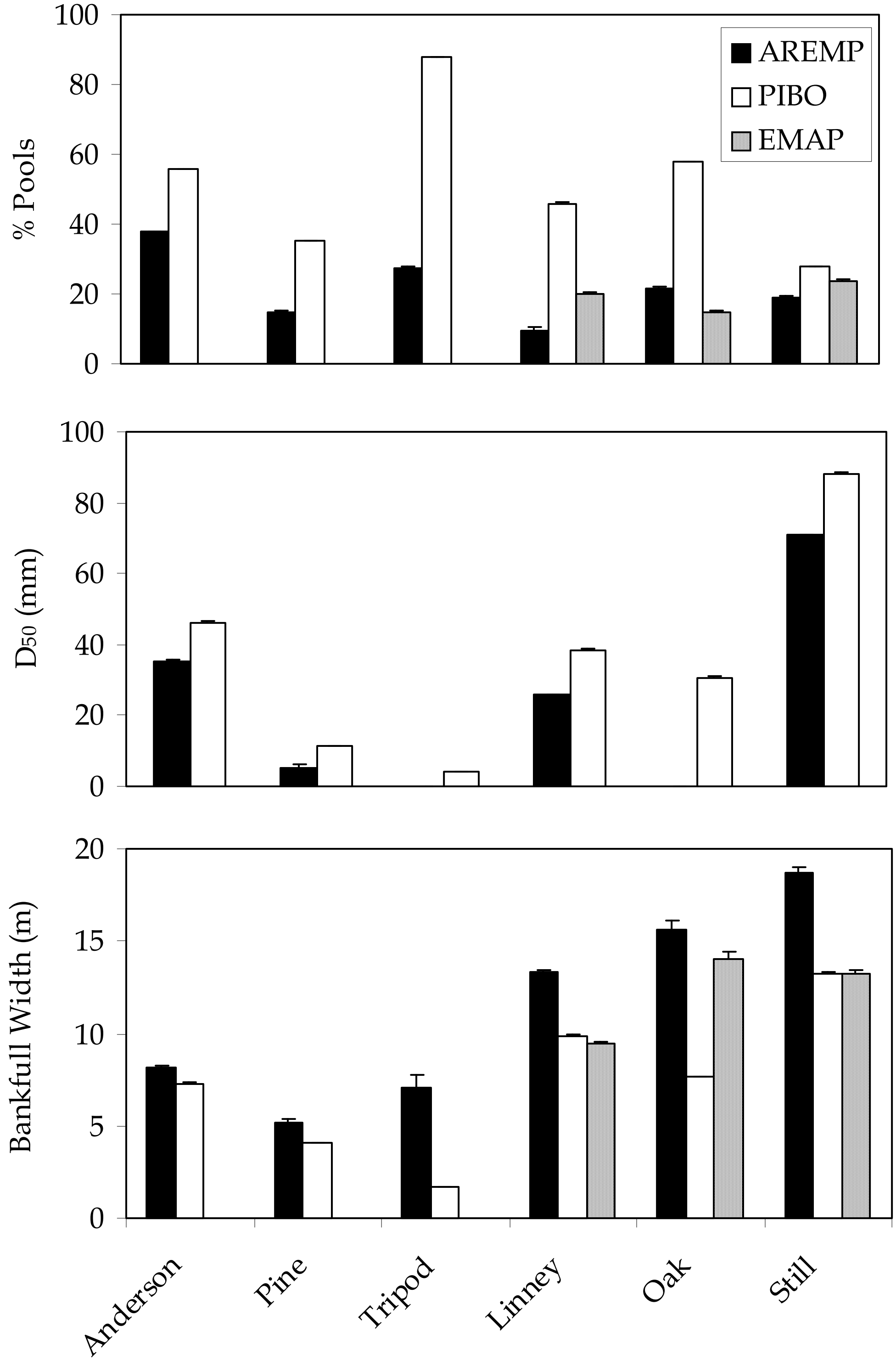

Figure 2. Mean differences between 2002 protocols for percent pools (top), substrate D_{50} (center), and mean bankfull width (bottom). Bars represent the mean of three replicate measurements by each program. Error bars represent one standard deviation. Anderson, Pine, and Tripod creeks are located in Idaho, Linney, Oak, and Still creeks are located in Oregon. AREMP = Aquatic and Riparian Effectiveness Monitoring Program, PIBO = the USDA Forest Service's monitoring for the Pacfish/Infish Biological Opinion, and EMAP = Environmental Protection Agency's Environmental Monitoring and Assessment Program.

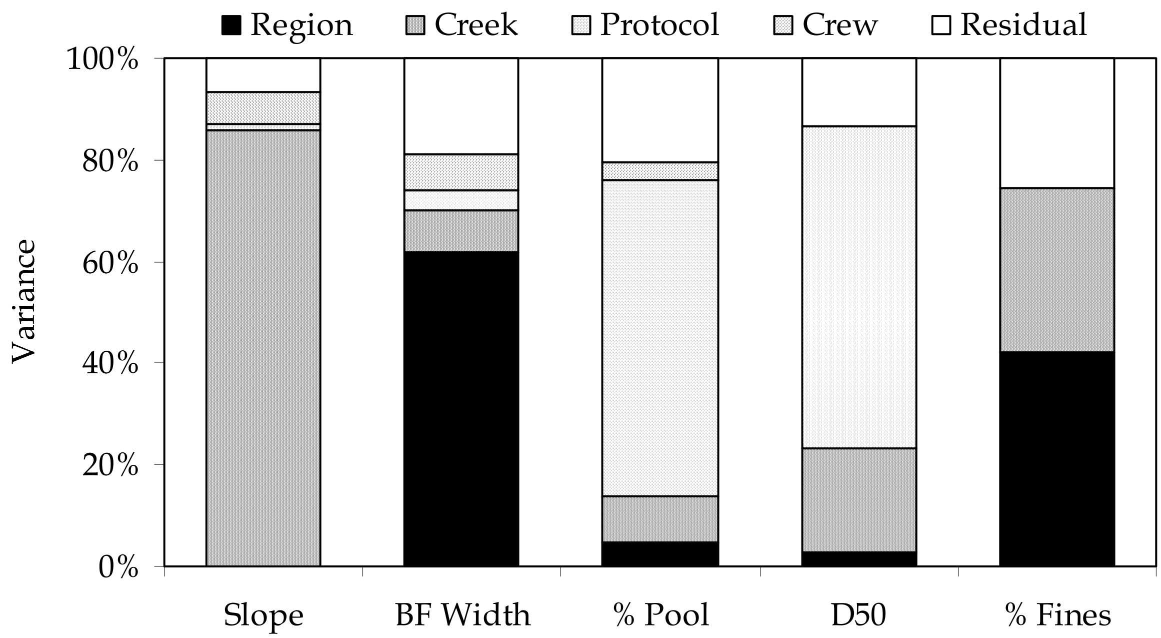

Figure 3. Results of the variance partition analysis among watershed monitoring programs during 2002. Percent contribution of each source of variance is given. These results are for AREMP = Aquatic and Riparian Effectiveness Monitoring Program, PIBO = the USDA Forest Service's monitoring for the Pacfish/Infish Biological Opinion, and EMAP = Environmental Protection Agency's Environmental Monitoring and Assessment Program

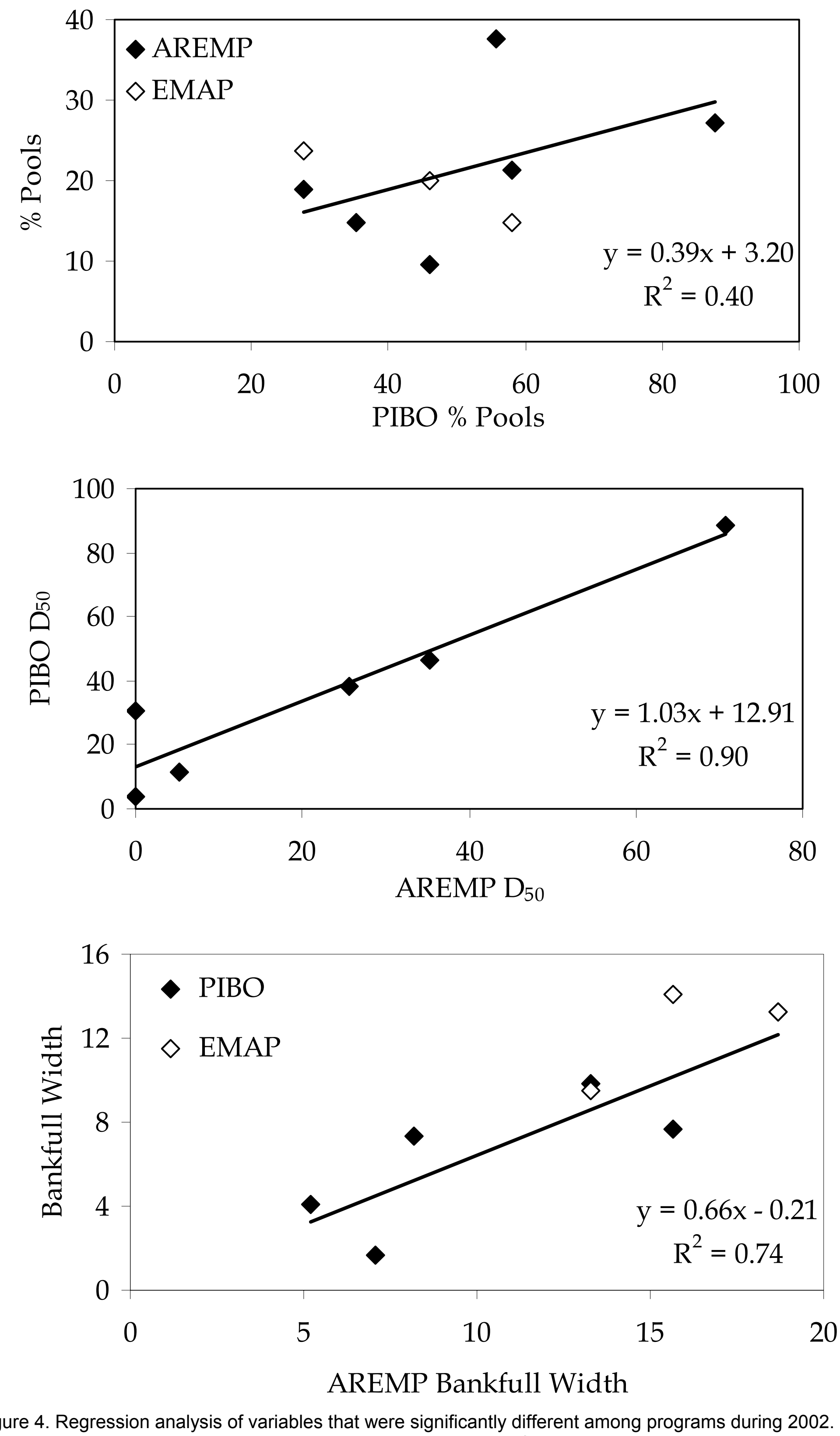

Figure 4. Regression analysis of variables that were significantly different among programs during 2002. Percent pools is presented in the top panel, substrate D_{50} in the center panel, and mean bankfull width in the bottom panel. AREMP = Aquatic and Riparian Effectiveness Monitoring Program, PIBO = the USDA Forest Service's monitoring for the Pacfish/Infish Biological Opinion, and EMAP = Environmental Protection Agency's Environmental Monitoring and Assessment Program.

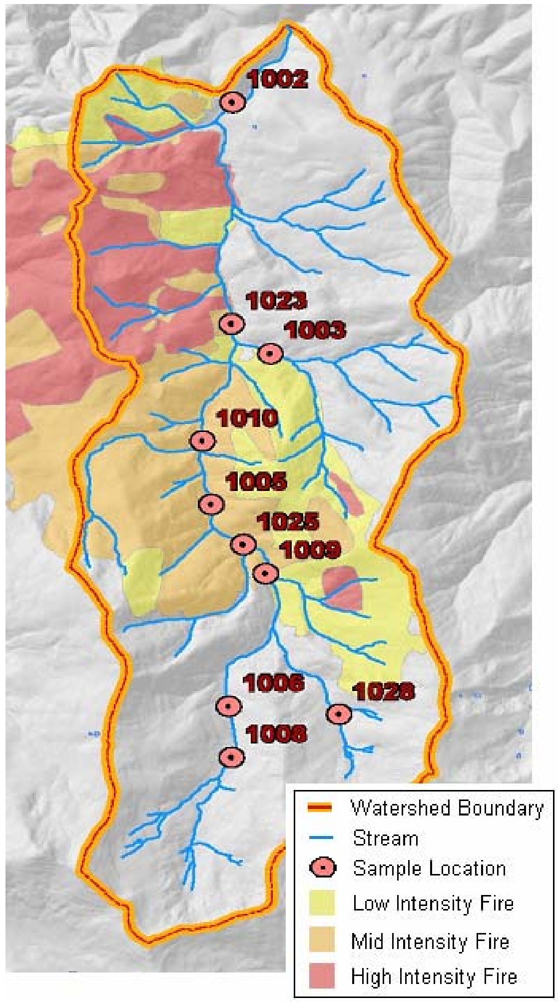

Figure 5. Glade Creek watershed map, Rogue River National Forest, Oregon. Shown are the 2000 and 2002 sample locations and 2000 fire intensity in the watershed.

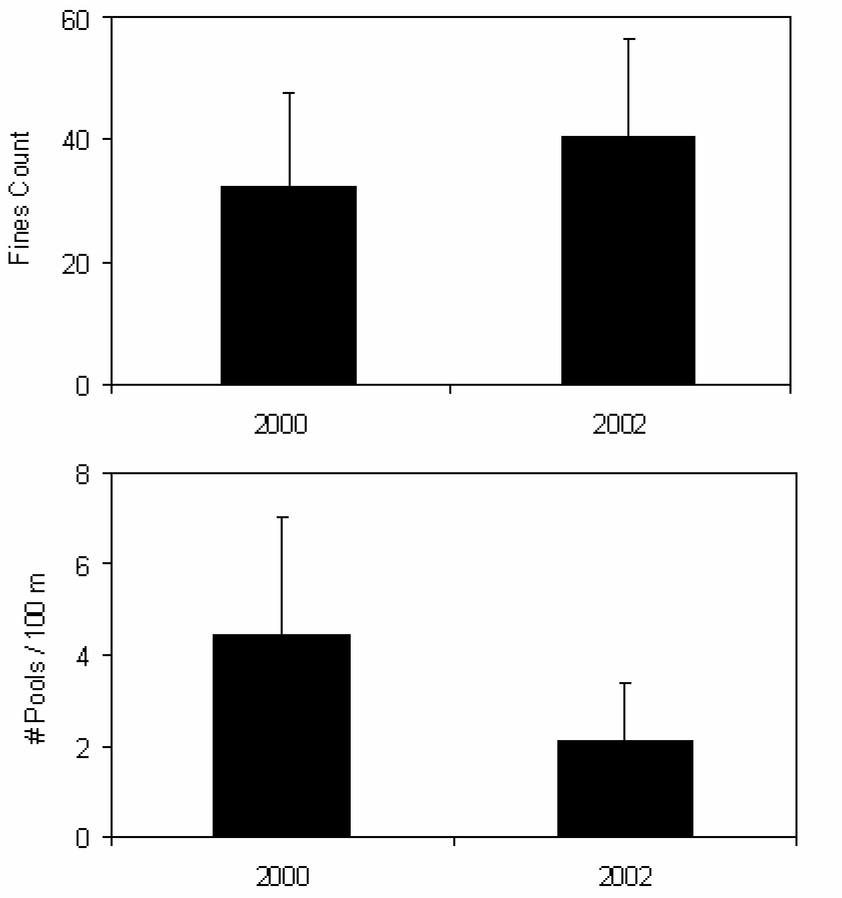

Figure 6. Mean difference in fines (top) and pool frequency (bottom) before (2000) and after (2002) the Quartz fire in the Glade Creek watershed, Rogue River National Forest, Oregon. Error bars represent one standard deviation.

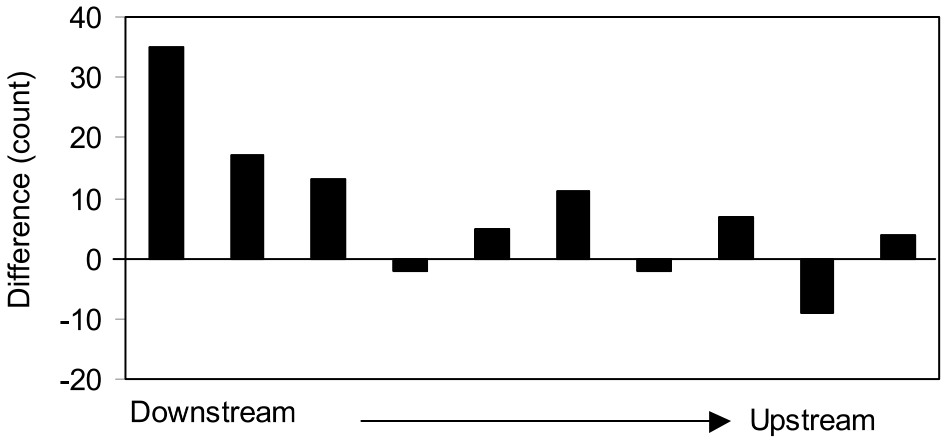

Figure 7. The difference in fines from 2000 to 2002 in sampled sites within the Glade Creek watershed, Rogue River National Forest, Oregon. Bars represent the difference in fine counts (2000-2002) at each site. Positive numbers indicate that more fines were measured in 2000 and negative numbers indicate that more fines were measured in 2002. The zero or “no difference” line is shown for convenience. Sites are ordered from downstream to upstream (see Figure 5).

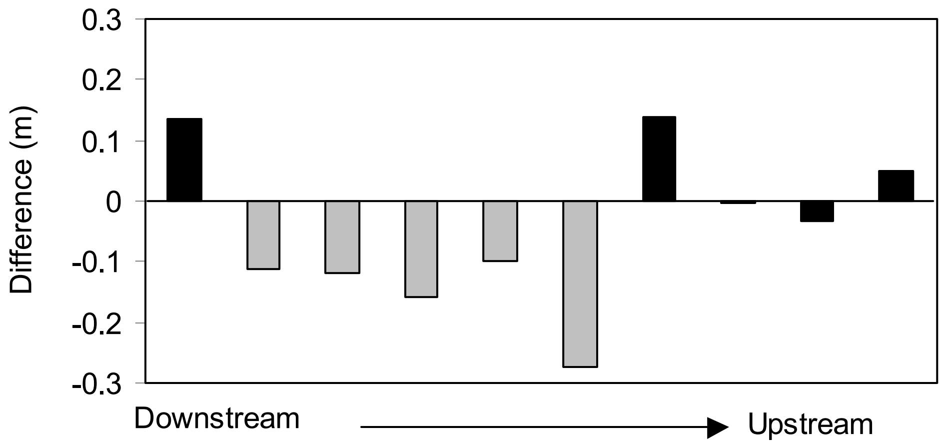

Figure 8. Changes in residual pool depth between 2000 and 2002 in sampled sites within the Glade Creek watershed, Rogue River National Forest, Oregon. Bars represent the difference (2000 – 2002) in average residual pool depth within sites. Positive numbers indicate deeper residual pool depths in 2002 relative to 2000, and negative numbers indicate shallower residual pool depths. Sites are ordered from downstream to upstream (see Figure 5). Grey bars indicate sites within mid intensity fire areas.

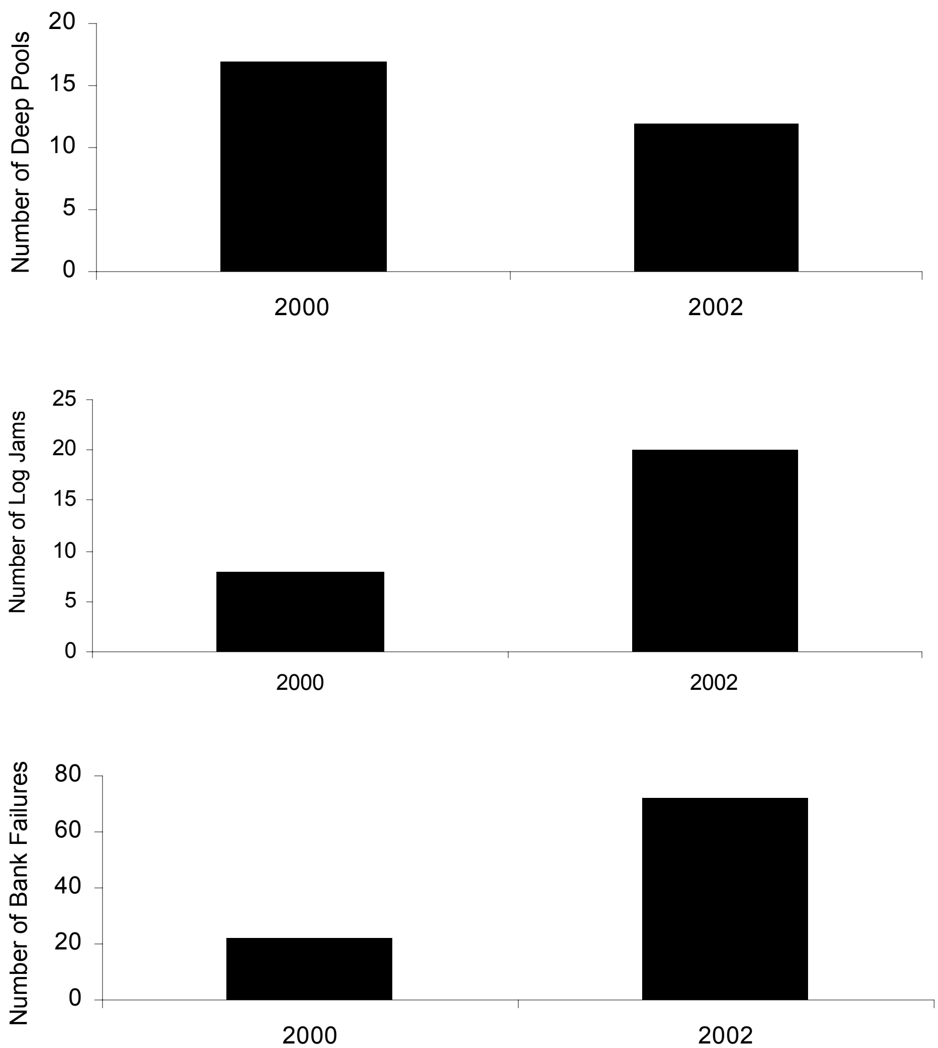

Figure 9. Number of deep pools (top), log jams (center), and bank failures (bottom) counted during the extensive surveys conducted in 2000 and 2002 within the Glade Creek watershed, Rogue River National Forest, Oregon.

APPENDICES

Appendix A. A comparison of protocols used by federal watershed monitoring programs in a protocol test conducted during 2002. The attributes included here are only those analyzed in the protocol test. A more comprehensive list is available online at: http://www.reo.gov/monitoring/watershed. AREMP = Aquatic and Riparian Effectiveness Monitoring Program. PIBO = the USDA Forest Service's monitoring for the Pacfish/Infish Biological Opinion, Oregon DEQ/EMPA = Oregon Department of Environmental Quality monitoring program based on the Environmental Protection Agency's Environmental Monitoring and Assessment Program.

Attribute	AREMP	PIBO	Oregon DEQ/ EMAP	FS R6 Level II Stream Survey
Reach Length	Reach length is 20x average bankfull width, with minimum and maximum lengths of 150 and 500 m, respectively.	Reach length is 20x average bankfull width with a minimum length of 80m.	Reach lengths for biological monitoring activities are defined as 40X the average wetted width of the stream (minimum length of 150 meters).	Reach length is based on geomorphic and hydrologic characteristics.
Channel Cross Sections	Non-constrained reaches: Eleven evenly spaced transects. Constrained reaches: Six evenly-spaced cross-sections	Uses methods adapted from Harrelson et al. 1997. Four cross-sections are measured within each reach. A cross-section is located at the widest point within each of the first 4 riffles.	Eleven evenly spaced transects are selected by dividing the reach into 10 equidistant intervals.	Not collected
Longitudinal Profile	Profile measured using a laser range finder and an electronic compass following thalweg. Shots are taken on an increment that is approximately 1/100 of the reach length. Additional measurements are taken at pool tail crests, maximum pool depth, and pool head.	Stream length is measured along the thalweg.	Profile measured following thalweg. Measurements are taken on an increment that is approximately 1/100 of the reach length. Additional measurements are taken at pool tail crests, maximum pool depth, and pool head.	Not collected
Pool Frequency and Length	Pools defined as being longer than the average wetted width and habitat unit has to be channel spanning.	To be measured as a pool, must occupy greater than half the wetted width, be longer than wide, include the thalweg, and the maximum depth is at least 1.5 times the crest depth. Length measured along the thalweg between the head and tail crest.	Calculated from thalweg depth and velocity measurements.	Pool defined as being longer than the average wetted width (unless unit is a plunge pool) and habitat unit has to be channel spanning.

Attribute	AREMP	PIBO	Oregon DEQ/ EMAP	FS R6 Level II Stream Survey
Gradient	Stream gradient is calculated as the rise of the streambed divided by the length of the sampling segment. Gradient is the slope of the streambed, not the water surface.	Stream gradient is measured from the water surface at the downstream end of the reach to the water surface at the upstream end using surveyor's rod and transit level. Elevation change is measured twice, with the level at a different position each time. If the two measurements are not within 10 percent of each other then a third measurement is taken.	Measured with laser range finder within sample reach, and calculated from maps using GIS.	Stream gradient is measured from 1:24000 USGS topo maps. It is calculated using rise/run of the stream reach (Channel Gradient is calculated by dividing the elevation gain by the mapped channel length for each reach).
Sinuosity	Calculated using longitudinal profile data. Sum of the distances between profile points divided by straight-line reach length.	Calculated as the length of the stream channel along the thalweg divided by the straight line distance between the top and bottom of the sample reach.	Calculated using longitudinal profile data. Sum of the distances between profile points divided by straight-line reach length.	Sinuosity is measured for each reach from a 1:24000 USGS topo map. It is calculated by dividing the channel length of the reach by the mapped valley length.
Bankfull width: depth	Calculate BF width to depth ratios at every cross section. Eleven depth measurements are taken between and including the BF points at each transect for determination of mean bankfull depth.	Mean bankfull depth determined from 10 measurements of depth in the cross section, taken at equal distances. First measurement is randomly chosen.	Calculate BF width to depth ratios at every cross section.	Bankfull width to depth ratio is calculated at each measured unit (10% of all units). Mean bankfull depth is calculated by taking the average of the measurements at ¼, ½, and ¾ points across the channel.

Attribute	AREMP	PIBO	Oregon DEQ/ EMAP	FS R6 Level II Stream Survey
Substrate	Percent surface fines in pool tail areas using USFS R5 SCI protocol. Grids are placed at 25%, 50%, and 75% of the distance along the pool-tail crest. Substrate particle size (D_{50}) determined by measuring 11 particles at systematic intervals within the 11 cross section transects.	Percent Surface Fines in Pool Tails: Using a modified version of USFS R5 SCI protocol. Grids are placed at 25%, 50%, and 75% of the distance along the pool-tail crest. 25 particles are sampled from each of the first 4 riffle/runs. Substrate Particle Size (D_{16}, D_{50}, and D_{84} in riffles/runs): uses Wolman (1954) method.	Substrate particle sizes are measured at five locations equidistantly placed on each of the eleven transects. An observation for the particle size at the base of a stadia rod placed on the left edge, right edge, at 25% across, at 50% across, and at 75% across. Ten randomly placed measurements are made within riffles using a 50 x 50 cm wire grid. Only sand and finer substrates are measured in this grid.	R6 uses the Wolman pebble count technique. It is performed two times in each stream reach at representative riffles with at least 100 pebbles collected at each count.

Appendix B. Aquatic and Riparian Effectiveness Monitoring Program (AREMP) results to determine whether gradient had an impact on protocol execution and if there was evidence to support stratification of sample reaches within a watershed by gradient.

Indicator	Slope Class	Model Terms Creek	Site	Error	Signal:Noise	Total Variance	Standard Deviation	Sample Size
% PTC Fines	<2%	49.11	245.15	0.77	380	295.03	17.18	30
% PTC Fines	>2% & < 4%	17.59	61.77	58.45	1	137.81	11.74	36
% PTC Fines	>4% & <10%	48.21	239.92	10.94	26	299.06	17.29	46
% PTC Fines	>10%	29.41	262.21	0.82	355	292.45	17.10	21
Ave Bankfull Width	<2%	5.92	0.49	27.90	0	34.31	5.86	30
Ave Bankfull Width	>2% & < 4%	4.33	0.75	8.80	1	13.89	3.73	36
Ave Bankfull Width	>4% & <10%	5.82	0.09	6.55	1	12.47	3.53	46
Ave Bankfull Width	>10%	1.64	0.48	2.30	1	4.42	2.10	21
Bankfull W:D	<2%	0.00	3.10	98.90	0	102.00	10.10	30
Bankfull W:D	>2% & < 4%	4.43	56.95	0.97	63	62.35	7.90	36
Bankfull W:D	>4% & <10%	1.30	41.11	0.40	106	42.80	6.54	46
Bankfull W:D	>10%	2.56	0.01	9.76	0	12.32	3.51	21
Conductivity	<2%	2427.38	17.96	141.72	17	2587.06	50.86	30
Conductivity	>2% & < 4%	3406.82	103.42	0.31	11252	3510.55	59.25	36
Conductivity	>4% & <10%	2296.87	1736.60	7.92	509	4041.40	63.57	46
Conductivity	>10%	1953.22	2.82	131.57	15	2087.61	45.69	21
D50	<2%	498.07	6563.46	0.81	8743	7062.34	84.04	30
D50	>2% & < 4%	0.94	878306.41	0.94	936181	878308.29	937.18	36
D50	>4% & <10%	0.61	480147.79	210540.60	2	690688.99	831.08	46
D50	>10%	21915.95	222.35	2880.21	8	25018.51	158.17	21
Dissolved Oxygen	<2%	2.20	1.74	0.67	6	4.60	2.14	30
Dissolved Oxygen	>2% & < 4%	3.12	2.71	0.08	72	5.91	2.43	36
Dissolved Oxygen	>4% & <10%	253.53	3.62	0.51	506	257.65	16.05	46
Dissolved Oxygen	>10%	7.53	0.00	1.29	6	8.81	2.97	21
Gradient	<2%	0.23	0.04	0.15	2	0.41	0.64	30
Gradient	>2% & < 4%	0.00	0.05	0.24	0	0.29	0.54	36
Gradient	>4% & <10%	0.63	0.02	2.77	0	3.43	1.85	46
Gradient	>10%	0.00	27.61	0.08	359	27.69	5.26	21
pH	<2%	0.56	0.01	0.11	5	0.67	0.82	30
pH	>2% & < 4%	0.44	0.06	0.02	30	0.52	0.72	36
pH	>4% & <10%	0.49	0.00	0.06	8	0.55	0.74	46
pH	>10%	0.40	0.00	0.17	2	0.57	0.76	21

		Model Terms						
Indicator	Slope Class	Creek	Site	Error	Signal:Noise	Total Variance	Standard Deviation	Sample Size
Pools/100m	<2%	0.34	0.19	0.36	1	0.89	0.94	30
Pools/100m	>2% & < 4%	0.61	0.23	0.37	2	1.21	1.10	36
Pools/100m	>4% & <10%	1.10	0.80	0.93	2	2.83	1.68	46
Pools/100m	>10%	2.12	0.00	0.58	4	2.70	1.64	21
Pools/m	<2%	0.00	0.00	0.00	1	0.00	0.01	30
Pools/m	>2% & < 4%	0.00	0.00	0.00	1	0.00	0.01	36
Pools/m	>4% & <10%	0.00	0.00	0.00	1	0.00	0.02	46
Pools/m	>10%	0.00	0.00	0.00	6	0.00	0.02	21
Sinuosity	<2%	0.02	0.00	0.04	1	0.06	0.25	30
Sinuosity	>2% & < 4%	0.00	0.00	0.06	0	0.06	0.24	36
Sinuosity	>4% & <10%	0.01	0.03	0.07	1	0.11	0.33	46
Sinuosity	>10%	0.00	0.02	0.00	11	0.02	0.14	21
Stream Length	<2%	1117.99	8038.07	0.35	26260	9156.41	95.69	30
Stream Length	>2% & < 4%	2432.36	1000.84	0.06	54006	3433.27	58.59	36
Stream Length	>4% & <10%	564.43	256.94	938.76	1	1760.13	41.95	46
Stream Length	>10%	1.50	1149.64	0.02	71029	1151.16	33.93	21
Total Nitrogen	<2%	0.00	0.00	0.00	288935930	0.00	0.04	30
Total Nitrogen	>2% & < 4%	0.00	0.00	0.00	18704932	0.00	0.04	36
Total Nitrogen	>4% & <10%	0.00	0.00	0.00	337483147313	0.00	0.01	46
Total Nitrogen	>10%	0.00	0.00	0.00	1143021674	0.00	0.02	21
Total Phosphorus	<2%	0.00	0.00	0.00	2881532	0.00	0.02	30
Total Phosphorus	>2% & < 4%	0.00	0.00	0.00	312403809825	0.00	0.00	36
Total Phosphorus	>4% & <10%	0.00	0.00	0.00	49509980957	0.00	0.00	46
Total Phosphorus	>10%	0.00	0.00	0.00	495245444	0.00	0.00	21
Wood/100m	<2%	9.22	2.66	2.01	6	13.89	3.73	30
Wood/100m	>2% & < 4%	3.83	6.39	0.24	42	10.47	3.24	36
Wood/100m	>4% & <10%	5.75	14.20	0.46	43	20.42	4.52	46
Wood/100m	>10%	21.30	11.98	5.51	6	38.80	6.23	21
Wood/m	<2%	0.00	0.00	0.00	2	0.00	0.04	30
Wood/m	>2% & < 4%	0.00	0.00	0.00	1	0.00	0.03	36
Wood/m	>4% & <10%	0.00	0.00	0.00	1	0.00	0.05	46
Wood/m	>10%	0.00	0.00	0.00	2	0.00	0.06	21

Appendix C. Members of the Regional Interagency Advisory Team, who provide guidance to the Aquatic and Riparian Effectiveness Monitoring Program.

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