Long-term Aquatic Monitoring (LTAM)

Study Design and Protocols

for Status and Trends Monitoring of Streams within the Cedar River Municipal Watershed

Hydrology Work Group
Ecosystems Section
Watershed Management Division
Seattle Public Utilities

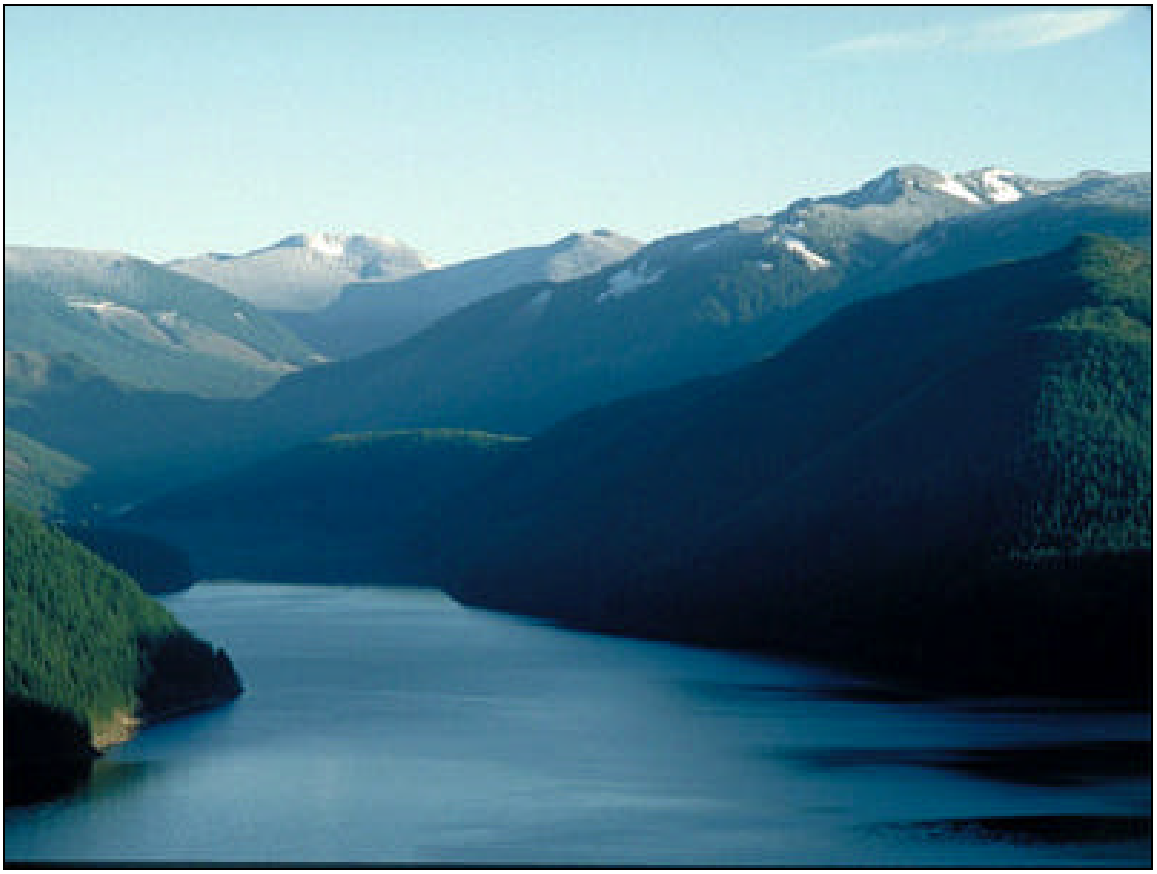
Long-term Aquatic Monitoring (LTAM)
Table of Contents

Section 6: Data Management

.Final Study Design for Status and Trends Monitoring of Streams Within the Cedar River Watershed

Phase II Draft Final Report

June 16, 2006



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Aquatic Monitoring Development – Phase 2
Contract No.:R00-34-18-01

Final Study Design for Status and Trends Monitoring of Streams Within the Cedar River Watershed

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Aquatic Monitoring Development - Phase 2

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Table of Contents

Tables

Figures

Front cover photo credit – Seattle Public Utilities Cedar River Watershed Website – virtual tour

1 INTRODUCTION

By virtue of the 50 Year Habitat Conservation Agreement, Seattle Public Utilities has committed to instituting a monitoring program that provides reliable data on existing stream conditions and how they might change over time. The goal of this project is for development of such a monitoring program – to yield **status and trends** in key physical (geomorphic) channel indicators for streams within the 90,000 + acre Cedar River Watershed. Once accumulated, this information will allow watershed managers to understand *present conditions* and *track stream channel changes over time* throughout the watershed.

This present report is the culmination of a two-phased approach. In the first phase, which ended in January 2006, recommendations were provided for conceptual approaches to designs intended for a status and trends monitoring program. The focus was on a statistically sound survey design framework that would align with the agreed to monitoring goals and objectives. After discussion with the Watershed staff, consideration of their work to date, and overall program objectives, a survey design approach using a rotating panel design was decided upon for further development. That refinement is the focus of this current report, which includes descriptions of the discrete list of specific physical channel parameters to be sampled during the monitoring plan implementation, as well as a master sample site list that is stratified according to susceptibility to change over time, as well as randomized and spatially balanced in terms of potential sites from which to populate the panels.

Over time, implementation of this monitoring program will help document the trajectory of recovery of channel geomorphic features from a legacy of natural and human disturbance. Insights gained from this program will inform watershed managers on the appropriate course of action for promoting recovery of both channel and fish habitat over time, and how local factors may control the timing and ultimate potential expression of conditions in a given stream. Also, these data will help establish ranges of conditions that can be expected with passive restoration strategies, and help prioritize where to apply more directed stream restoration actions within the watershed.

Because of regional consistency in selection of stream variables and the field protocols chosen, results can be compared with those from similar efforts concentrated on federal and state forested watersheds, to provide a regional context. In the following pages, a sampling scheme is defined in which investments in field sampling efforts can be predictable from year to year, and distributed throughout the watershed in such a way as to provide reliable status and trend information throughout the remaining years of the Habitat Conservation Plan permit terms.

Additional background information on this project is contained in the final report for Phase I of this contract, delivered to Seattle Public Utilities in January of 2006.

1.1 Study Objectives

The associated study objectives are:

1. Refine - and explicitly state - questions of interest in order to define criteria needed for proper design of sampling scheme. These were initially discussed in the report associated with Phase I of this project, and have been distilled and restated as hypotheses below.
2. Make recommendations on physical channel parameters (i.e. geomorphic features relevant to aquatic habitats).
3. Select an approach that will allow results to be compared to aquatic monitoring efforts from similar geographic areas in the Pacific Northwest.
4. Define options and make a recommendation on a statistically robust sampling design that provides reliable and comparable measures of key indicators of aquatic resource conditions meaningful at the broader watershed and landscape scale.
5. Consider how the overarching monitoring design might take advantage of ongoing effectiveness and cause-effect related monitoring – being done within the watershed.

Each of these study objectives is addressed in the sections below.

1.2 Scope of Work

The scope of this study includes:

1. Identify key geomorphic features of interest that are ecologically relevant and reflect watershed and channel processes that are tractable over time.
2. Identify appropriate field methods.
3. Define hypotheses associated with key geomorphic features.
4. Define a statistically robust sampling frame to ensure spatially distributed sites that over time will yield status and trend information on key geomorphic features of response reaches.

The physical scope of this monitoring program includes all of the Cedar River Watershed within the domain of the Seattle Public Utilities. This approximately 90,000 acre area includes all of the watershed above the Landsburg Diversion Dam, upstream to the Cascade Mountain crest that defines the hydrologic boundary of the watershed. The tributaries and mainstem Cedar River below Chester Morse Reservoir and Masonry Dam are also included. However, different field methods will be required to sample the main Cedar River as its size precludes use of those suitable for streams that can be safely waded on foot.

Stream reaches having channel gradients less than 4% are generally both the most biologically active and most susceptible to changes in the inputs of wood, water and sediment (Montgomery and Buffington 1997, 1998). For purposes of this initial study design, only response reaches are included in the potential sites for sampling. This level of channel classification is at the coarse scale, and is based solely on the channel gradient and confinement. Ensuring that sites to be sampled are spatially distributed, representative and randomly selected, a "master sample" of response reaches was generated using a GRTS algorithm (GRTS is discussed in the Phase I report). Each site on the ordered list will be evaluated to verify that it meets the "response" reach criteria before final inclusion in the sampling frame. Subsequent analysis of the data will consider the influence of more refined channel type delineation (e.g. plane-bed and pool/riffle type channels) to help explain possible variance.

In order to adhere to the randomized site selection, sampling sites were chosen with no regard to their proximity to other sites associated with ongoing studies within the watershed. However, it is expected that over time, many selected sites will fall within close proximity to established permanent riparian sample plots, and stream macroinvertebrate sampling sites involved with ongoing USGS studies.

After initial discussions with SPU program managers, the focus on biotic communities was put off until budget limitations were better understood. A separate approach to amphibian status and trend monitoring, using a similar site selection process and panel design, will be evaluated in the summer of 2006. However, at this point, no effort has been made to conduct a sensitivity analysis to inform as to how many amphibian sites will be needed to construct an appropriate sampling panel for status and trend monitoring and how frequently they might need to be surveyed. That analysis awaits the results of the pilot efforts conducted this year to gauge the reliability of the field amphibian detection survey methods.

1.3 A broader context for the results of the monitoring program

Understanding how stream channel conditions within the watershed compare to those found by others in similar watersheds is an important objective of this study. Fortunately, a considerable amount of effort has been put forth in recent years to better coordinate federal, state water quality, stream channel and aquatic community monitoring. EPA's western adaptation of their EMAP program has lead to refinement of both a sampling scheme using rotating panels, as well as evaluating sources of variability and change detection associated with the field methods used for parameters of interest. Similarly, coordination among federal and state agencies engaged in stream and aquatic biota monitoring throughout the Pacific Northwest has progressed in recent years. The Pacific Northwest Aquatic Monitoring Partnership (PNAMP) provides a forum for coordinating state, federal, and tribal aquatic habitat and salmonid monitoring programs. Improved communication, shared resources and data, and compatible monitoring efforts provide increased scientific credibility, cost-effective use of limited funds and greater accountability to stakeholders. PNAMP provides leadership through the development and the advancement of recommendations and agency level agreements that are considered for adoption by the participating agencies. More information is available from the PNAMP website at- http://www.pnamp.org/web/.

While the survey field techniques recommended in this monitoring program are different in terms of precision than those used by EMAP and PNAMP, the stream parameters are the same and the higher resolution techniques recommended be used in the CRW ensure comparability of the results with similar measures from these two programs. Through this means, status and trend information from the Cedar River Watershed can be compared to similar data throughout the Pacific Northwest.

1.4 Development of sampling design and site selection

Below, we identify final design details including selection of key indicator variables to be measured during the course of the monitoring. These details include: (1) recommended physical channel parameters; (2) field methods to be used that provide the requisite level of resolution; (3)

respective hypothesis to help focus the eventual analysis; and, (4) descriptions of options in terms of panel designs, re-visit frequencies, power analyses, numbers of sites visited each year (annual effort), and related topics.

2 RECOMMENDED SAMPLING PARAMETERS AND METHODS

The purpose of this monitoring program is to provide a snapshot of existing conditions (status) and in subsequent years of data collection, document changes over time (trends) in key geomorphic conditions within response reaches distributed across the watershed.

2.1 Recommended parameters

The recommended parameters to be measured at each stream sample site include three physical geomorphic features, water temperature, and a photo documentation of stream conditions at each site, as shown in Table 1.

Table 1. Recommended physical stream parameters and measurement techniques for status and trend monitoring.

Category	Recommended Physical Parameter	Measurement Technique
Pools	*Residual pool depth* – distribution of pool depths by sample site of all pools/length of stream *# pools* – per unit length (gives distance between) *# pools formed by wood* – by sampled site, expressed as a %.	Longitudinal profile using auto level and rod. Include three cross-sections/sample site to augment interpretation of other channel geometric measures.
Woody Debris	*# pieces* per unit length of stream *# pieces/ size class* = volume estimate *Position in channel* – zones defined within active channel	Data sheet will include provisions to assign pieces into size categories, and will distinguish "jams" of > 5 pieces; and assign pieces to 4 zones within the channel*
Sediment	Cumulative size distribution – *D50 and D85*; estimate of % size fraction < 0.85 mm	Wolman (1964) pebble counts, 3 counts per sample site, at permanent cross-sectional transect locations
Stream Temperatures	*7 day average of the daily max*	Recommend sample interval at 2 hr interval or greater. Thermisters installed at each site.
Photo points	Establish *permanent photo points:* both upstream and downstream of sample reach midpoint, downstream from uppermost boundary and upstream of lowermost boundary.	

** Or substitute SPU field methods for LWD data collection.*

2.2 Hypotheses Associated with Selected Channel Metrics:

2.2.1 Pool characteristics

a) *Residual pool depth – Ho:* Residual pool depth remains unchanged over time both within and between sites.

   Ha: Residual pool depths will increase over time as sources and inputs of sediment (from hillslope and bank erosion) stabilize and are reduced; and existing accumulations of fine sediments are winnowed from stream beds and transported downstream.

b) *Numbers of pools – Ho:* The number of pools remains unchanged over time both within and between sites.

   Ha: The number of pools per unit length of stream will increase over time as obstructions to flow (wood inputs) increase, sediment supply decreases and annual stream flow characteristics stabilize.

c) *Pools formed by wood – Ho:* The number of pools formed by wood remain unchanged over time.

   Ha: The number of pools formed by wood per unit length of stream will increase over time.

2.2.2 Woody debris

a) *Woody debris pieces – Ho:* The number of pieces of woody debris per unit of stream channel will remain unchanged over time, both within and between sites.

   Ha: The number of pieces of woody debris per unit length of stream within response reaches will increase over time.

b) *Woody debris volumes – Ho:* The volume of wood will remain unchanged over time, both within and between sites.

   Ha: The volume of wood in response reaches will increase (i.e., number of pieces/ size class, as riparian zones recover from past logging).

c) *Position in channel – Ho:* Woody debris size classes and distribution within the active channel will remain unchanged over time, both within and between sites.

   Ha: As the size of woody debris increases, more pieces of larger size will be positioned within the wetted width of the channel during base flow periods (i.e., in late summer/early fall months).

2.2.3 Sediment

Sediment particle size distribution – Ho: Sediment particle size will remain unchanged over time, both within and between sites.
Ha: the cumulative size distribution of the 50% and 85% particles will increase over time as sediment supply and flows equilibrate to more natural input processes (*D50 and D85*; estimate of % size fraction < 0.85 mm).

2.2.4 Stream temperatures

Stream temperature – Ho: Stream temperatures regimes during the summer months will remain unchanged over time

Ha: Stream temperature regimes during the summer months will correspond to those expected for streams un-impacted by commercial scale timber harvesting, and nominally conform to established water quality temperature criteria as evidenced by the moving, 7-day average of the daily maximum (MWAT) temperature.

2.3 Recommended Field Methods

2.3.1 Longitudinal profile

Techniques to capture these channel features can vary widely in terms of repeatability, which greatly affects the ability to detect changes over time. To ensure greatest reliability, we recommend establishing longitudinal profiles by the use of a rod and level adhering to principles of basic survey techniques. The longitudinal profile of a stream channel captures topographic variation of the channel bed surface.

Typically the long profile is measured along the thalweg, or deepest and swiftest part of the channel. A key attribute that is measured using a longitudinal profile is the *residual pool depth* of individual pools (topographic lows). Residual pool depth is the difference in bed elevation of a topographic low (a pool bottom) with the next downstream topographic high (usually a riffle crest). Pool frequency can also be defined using a longitudinal profile. All of these measurements give important insights into the characteristics of channel features that are significant to support of biotic communities.

Typically measurements are taken from downstream to upstream from a *benchmark* or *monument* that is established at the outset of measurement. The benchmark must be carefully established and surveyed because all subsequent measurements (including future, re-surveys) are tied into the first benchmark. The most important aspect of the longitudinal profile survey is that it be easily repeatable so that changes and trends can easily be tracked over time; thus extreme care is requisite in establishment of easily located benchmarks or monuments construction. Chapter 5 of Harrelson et al. (1994) provides an excellent overview of basic surveying techniques, including defining benchmarks and monuments construction. Chapter 8 of Harrelson et al. (1994) is a synopsis of the procedure for measurement of longitudinal profiles.

2.3.2 Cross-sectional profile

Channel cross-sectional profiles provide a snap shot of the relationship between channel width and depth at a site. Several cross-sections along a study reach, which are coupled with a longitudinal profile, help define an instantaneous, characteristic physical description of the reach of interest. Repeat surveys over a period of years can establish a trend of channel change.

The procedure for measuring a channel cross-sectional profile is essentially identical to that used for a longitudinal profile. A benchmark or monument must be established and its elevation surveyed to tie it into the initial benchmark that was established at the outset of the longitudinal profile survey. Chapter 6 of Harrelson et al. (1994) covers the basic techniques for measuring a channel cross section.

For this survey, it is recommended that three channel cross-sections be done per site, with permanent head-pins and tail-pins established for future, repeat surveys.

2.3.3 Surface particle size distribution

Surface particle size distribution is a technique used to define the basic relationship between sediment supplied to the channel and the stream capacity to transport that sediment. In the response reaches in which these surveys are taking place, it is expected that trends in bed surface particle size would be relatively easy to detect if any change were taking place. Bed surface particle size would be expected to co-vary with both channel width and with residual pool depth. Pool frequency and particle size may also co-vary.

For example in a disturbed basin, it is expected that the sediment loading would increase, and thus the bed surface particle size would decrease. A commensurate shallowing and widening of the channel is often commonplace in this situation; In addition, pool frequency may go down as shallow pools are filled in by the increased sediment loading. As the basin and channel recover from the disturbance, a modest reversal of the initial trends described above may be observed over time.

Bed surface particle size distribution is determined using the method of pebble counts (Wolman 1954). Pebble counts consist of measuring the intermediate axis of a 100 particles selected at random from the surface of selected point bars in the survey reach. The details of pebble count techniques are presented in chapter 11 of Harrelson et al. (1994). The most important aspect of completing a pebble count is reduction of bias by the person who is selecting and measuring particles. It is paramount that particles be selected at *random* from the bed surface. Site selection for the pebble count is also very important. Choose an exposed point bar that has plenty of well sorted stones. A point bar is the cuspate deposit of cobbles or gravel that is often present on the inside of meander bends. Point bars represent the frequently transported and deposited fraction of bedload, and reflect the most recent relationship between the sediment supplied to the channel and its transport capacity. If no point bars are available (for example in a steeper, straighter plane bed channel) then an expanse of well sorted stream bed will do.

2.3.4 Woody debris

The supply of woody debris to the channel is a function of the source supply characteristics, the degree of both man-made and natural disturbance in the basin, including changes in the composition of the riparian plant community. Prior to early 1990's, when the City consolidated ownership within the watershed, substantial commercial scale forest extraction occurred within the basin, and upland areas and riparian zones were substantially altered in several sub-basins. In some areas, this left little in the way of riparian vegetation to provide recruitment of large woody debris to the stream channel. As a consequence, in-stream woody debris is likely limited in some if not most of the streams within the upper basin, where logging was most concentrated (Ralph et al 1994, Fox 2003).

In Western Cascade mountain streams, large woody debris provides an important roughness element to many streams, and accounts for both channel and aquatic habitat complexity because of flow velocity deflection and obstruction. Scour pool and bed surface texture and topographic variability are associated with deposits of large wood in stream channels.

After discussions with science staff members at the Cedar River watershed, the sampling techniques that will be used to sample woody debris will be the same as are currently used for other site-level effectiveness monitoring within the watershed. Details on these techniques are therefore not provided here. The relevant characteristics of woody debris that should be sampled include the number of pieces per unit length of stream; the number of pieces per a given size class (3 size classes) in order to get an estimate of wood volume, and the position of key pieces (largest size class) relative to lateral zones within the active channel.

3 SELECTION OF STREAM SAMPLING SITES

As discussed earlier in the Phase I report, the sampling scheme involves use of sample sites selected from a "master sample" list generated through the geographic randomized tessellation system (GRTS) currently used by the US EPA EMAP program, as well as the Oregon Department of Fish and Wildlife for their coastal coho sampling scheme. This master sample was generated using a 1:100,000 scale hydrography layer (USGS), with sites randomly selected as intersection points within represented stream systems. This technique results in an order list of potential sampling sites.

This list was further refined by selecting only those sites that fell within stream reaches that had gradient characteristics (< 4%) that correspond to "response" reaches (Montgomery and Buffington 1997, 1998). Response reaches are generally lower gradient, unconfined or moderately confined reaches of streams that are most likely to change in response to inputs of wood, water and sediment. Response reaches are often considered the most biologically active and susceptible to changes associated with increases or decreases in material input processes.

3.1 Selection of Sample Sites to Populate the First Year's Panel

Using the master sample list to select the sample sites to populate the first year sample panel is quite simple. The sites that meet the criteria of response reaches are ordered in a random fashion. Regardless of the number of sites to be sampled in the first year, one simply goes to the first site on the list, and evaluates it in terms of its conformity with its geomorphic characteristics; for example, is it truly a "response" reach, or has it been misidentified. If the first site is chosen, one moves onto the second site in the master list, and that site is subject to the same sort of evaluation. If a site is rejected, simply move on down the list and select an alternative site, until the requisite number of sites have been selected that together, constitute the first year panel.

There is an interest in associating the status and trends sites within proximity to "riparian sample plots". Figure 1 shows the relative proximity of the first 20 response reach sites from the master sample list to the established permanent riparian plot sites. Deliberately selecting or rejecting sampling sites based on their proximity to other sites of interest would violate the spatially randomized element of the study design, and compromise the statistical rigor of the resulting data. However, given the finite size of the basin, some unknown number of sites selected for this monitoring study will inevitably coincide with other locations of interest, adding to the texture of interpreting the results.

Similarly, Figure 2 shows the relative proximity of the first 20 sample sites from the "master sample" to the network of sites recently sampled by the USGS to establish the benthic index of biotic integrity (BIBI) sites.

In addition, there is an interest in creating a sampling panel design for systematic sampling of stream locations to establish status and trends in key amphibian species within the watershed. Identifying potential sample sites from the master sample of stream reaches--that are likely to provide habitats for these species--is relatively straight forward. Very likely, gradient and fish presence are correlated with the occurrence of amphibian species of interest. Gradients > 7% corresponding with source and transport reaches, are likely candidates. The master sample list can be re-sorted to include only those sites corresponding to this defined gradient criterion. The list can be further parsed to eliminate those with know occurrence of fish species that likely limit or restrict amphibian populations.

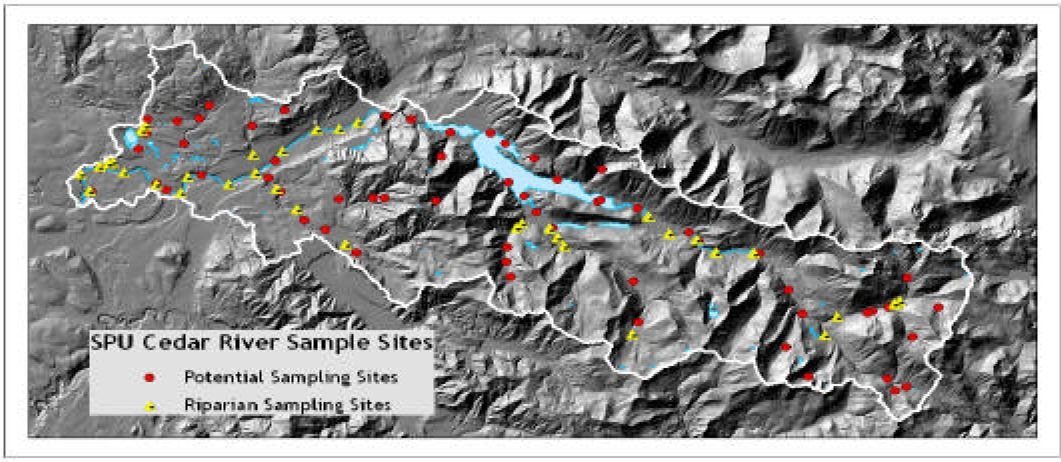

Figure 1. Proximity of response reaches from master sample to permanent riparian sample plots within the Cedar River Watershed.

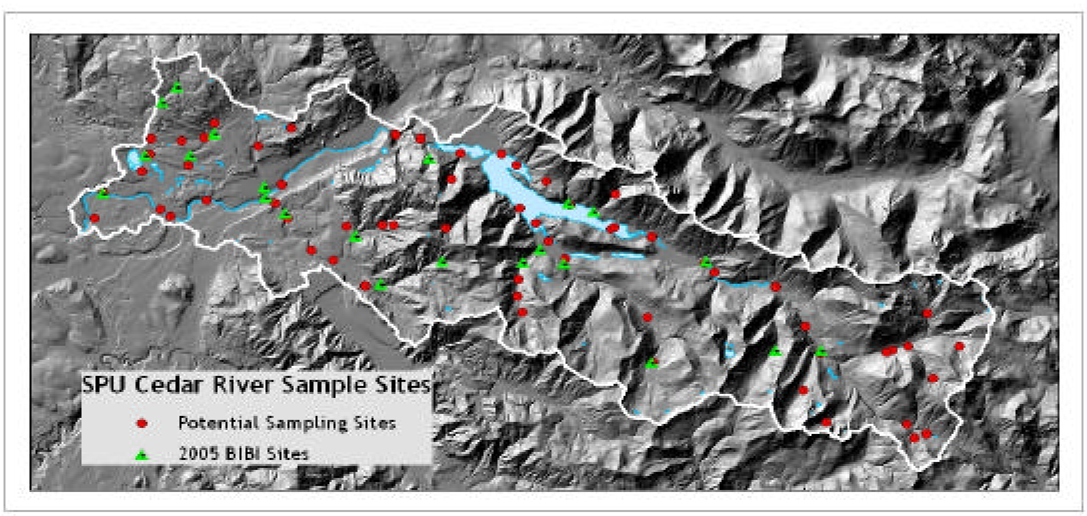

Figure 2. Proximity of response reach potential sampling sites to BIBI sampling sites established within the Cedar River Watershed.

4 RESULTS OF POWER ANALYSIS FOR RECOMMENDED PARAMETERS, SAMPLE SITE SELECTION AND FREQUENCY

4.1 Power Analysis—Data Used and Approach

A limited set of exploratory data analyses were done to facilitate final sampling design decision-making. This task included some power analyses to look at some available data and/or obtaining variability estimates from the literature. Power analyses was done to provide useful information for evaluating trade-offs among final design options, for determining sample sizes and frequency of sampling.

Finding stream sampling data for the selected parameters of interest proved to be somewhat difficult, especially finding time series data, whereby multiple years of measurements were taken at the same location. Initial contact with an ongoing PNAMP project looked promising, as the USFS was also conducting some side by side trials of differing field protocols, and they were analyzing data sets from their many decades of field work. In the end, however they were unable to share their data in time for this analysis to conclude.

Absent successive year sampling data from a few sites, this analysis used single year data from multiple sites throughout Washington. Specifically, field sampling data from the original University of Washington ambient monitoring program was used (Ralph et al. 1991, Ralph et al. 1994). This data was collected in 1989–1991, with standardized field methods for all of the parameters of interest for this current effort. The field methods were less repeatable, using techniques with less precision than the engineering standards called for by the use of an auto-level and rod survey techniques. However, the data do provide information that can be used to make relative comparisons among various sampling designs.

4.2 Parameter Estimation for Residual Pool Depth

We estimated statistical power for residual pool depth normalized by segment length. The distribution of site means are based on average residual pool depth divided by segment length for 26 segments of Timber Fish and Wildlife (TFW) data collected in 1990 and 1991. A segment is considered to be the experimental unit and the TFW data set contains residual pool depth measurements for all pools in a given segment. The residual pool depth for all pools in a segment were averaged and then normalized by the segment length. Averages were normalized by segment length due to the variable length of the segments, which tends to correlate with the number of pools included in the estimates of averages. Normalized averages were computed for 26 segments. The combined 1990-91 data set included a total of 92 segments surveyed on 37 streams. In order to control for probable correlation among segments on the same stream, we limited our selection to one segment per stream. The segment for each stream was randomly selected from the available segments for that stream. Eleven segments were discarded for lack of information on segment length. Although sampling took place over two years, no segments were visited more than once. We assume that there was no regional trend over the two years, and treat the observations as the best available estimates of current residual pool depth conditions for each segment.

The distribution of the 26 normalized segment means was right-skewed, so a log transformation was applied to the data to obtain a set of approximately normally distributed means. The distributions of log-transformed site means (n=26) were tested for departures from normality using Shapiro-Wilks tests with alpha = 0.05. No violations of the distributional assumptions were found (*p* = .6261). Plots of the normalized segment means distributions are shown in Figure 3. Based on maximum likelihood methods, the normal parameters, estimated in log space are: mean = -8.368 and standard deviation = 1.064.

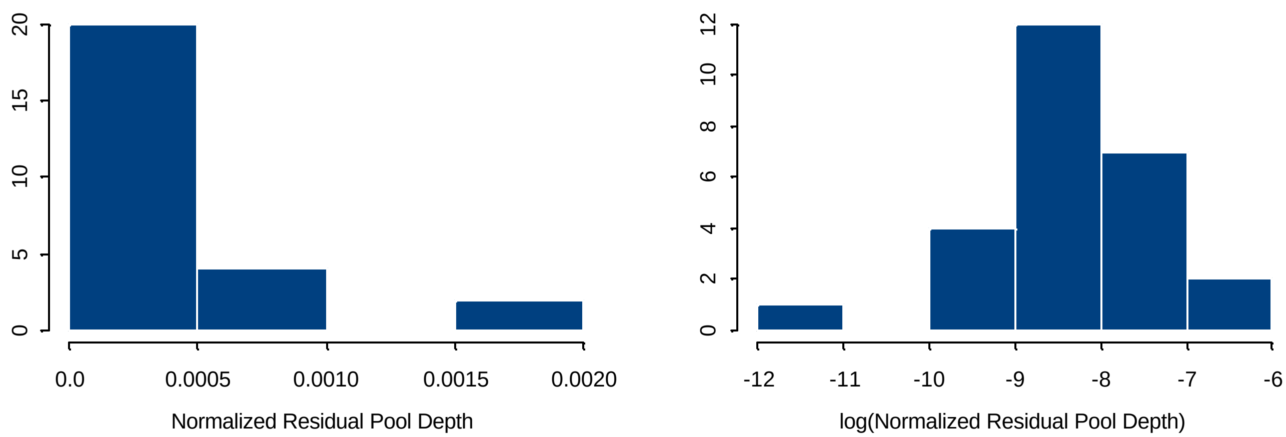

Figure 3. Plots of means and log (means) of residual pool depth for 26 segments from the 1990-91 TFW data set.

An estimate of inter-annual error (annual fluctuations in residual pool depth unrelated to trend; this includes sampling error and temporary weather-related changes) is needed, but cannot be divulged from this two-year data set since none of the segments were revisited each year. In order to come up with some sort of error distribution, we generated 2,550 residuals for each pool in the 26 segments. Residuals were calculated as measured residual pool depth minus the grand mean, where the grand mean was the mean of the 26 mean residual pools depths calculated for each segment. This is not the best estimate of inter-annual error, but without additional data there is not much else to go on. We are basically assuming a type of space for time substitution when using this estimate for the error term. Due to the uncertain nature of our inter-annual error estimate, a low variance estimate equal to half the inter-annual error and a high variance estimate equal to twice the inter-annual error for the TFW-based estimate were also tested to evaluate the effect of this variance estimate on statistical power. Additional data, especially time-series data could be analyzed, if it were to become available.

A plot of the residual pool depth residuals is shown in Figure 4. The distribution of the 2550 residuals is right-skewed, with a few larger values. Results of a Shapiro-Wilks tests with alpha = 0.05 show violations of the normality assumption. Although this is not ideal, this is the best estimate of variability that we have, given the data. Assuming a normal distribution with zero mean, the standard deviation of the residual distribution was estimated as 0.294. This value was transformed, using mean segment length (based on the 26 segments in the sample), to represent a standard deviation for normalized residual pool depth. The normalized standard deviation was estimated as 0.0001. Power estimates were thus conducted using normalized standard deviation values of 0.00005, 0.0001, and 0.0002.

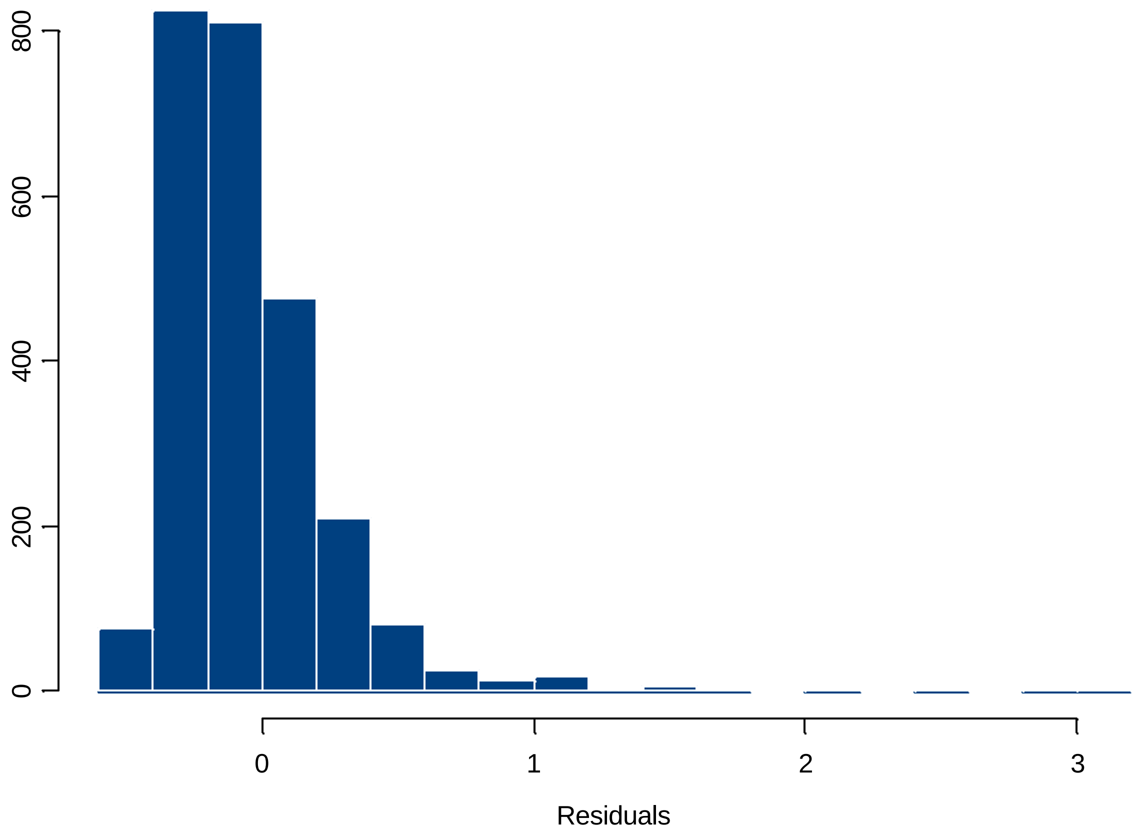

Figure 4. Plot of 2550 residuals calculated as residual pool depth minus grand mean of residual pool depth for data from 26 segments in the1990-91 TFW data set.

5 SIMULATIONS

To examine the relative merits of various designs, simulations were conducted for each of four panel designs, as shown in Tables 2 and 3. Designs 1 and 2 use unconnected rotating panels having five and three year revisit patterns, respectively. The annual level of effort for each designs 1 and 2 are similar, but not identical. Design 1 has eight sites per panel for a total of 48 sites, while design 2 has ten sites per panel for a total of 40 sites. Designs 3 and 4 are connected designs with identical annual effort, although the total number of sites differs. Design 3 has seven panels, each with five sites per panel. Two panels are visited each year, resulting in ten sampled sites per year. Sites are revisited two years in a row with five years off before the next revisit. Design 4 has five panels, each with five sites per panel. Two panels are visited each year, resulting in ten sampled sites per year. Sites are revisited two years in a row with three years off before the next revisit.

For each design, we used one trend detection method (profile summary using linear regression slope), four trend scenarios (+/- 2% and +/- 4% linear trend), and one alpha level (0.05). A no-trend scenario was included to verify the Type I error rate.

The profile summary using linear regression slope methodology uses the method of least squares to calculate best fitting linear trend lines for each average residual pool depth at each site. The slope estimate of the measured variable regressed on time is the summary statistic. There are no assumptions explicitly required for calculation of this estimate. The slope estimates of the trend lines are tested for differences from zero using a parametric *t*-test or a non-parametric *t*-test analogue. A non-parametric one-sample *t*-test assumes that the data compose a random independent sample from the population of interest. Thus, it is assumed that the population is well represented, and the segments are not influencing one-another. The parametric test requires the assumption of a normal distribution. The central limit theorem might be used to argue for normality of the slope estimates. The central limit theorem relies on the slope being a weighted sum of random variables, which is the case. If the result is significant, we infer that there is a general trend for the population.

Table 2. Unconnected panel designs.

Design 1	**N = 48 sites**																		
	8 sites/panel; visit 8 sites per year																		
	Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	1	X						X						X					
	2		X						X						X				
	3			X						X						X			
	4				X						X						X		
	5					X						X						X	
	6						X						X						X
	Calculate power after 12 and 18 years																		
Design 2	**N = 40 sites**																		
	10 sites/panel; visit 10 sites per year																		
	Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**		
	1	X				X				X				X					
	2		X				X				X				X				
	3			X				X				X				X			
	4				X				X				X				X		
	Calculate power after 8, 12, and 16 years																		

Table 3. Connected panel designs.

Design 3	**N = 35 sites**															
	5 sites/panel; visit 10 sites per year															
	Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
	1	X	X						X	X						X
	2		X	X						X	X					
	3			X	X						X	X				
	4				X	X						X	X			
	5					X	X						X	X		
	6						X	X						X	X	
	7	X						X	X						X	X
			not included in the analysis													
	Calculate power after 15 years, based on 4 points															

Design 4	**N = 25 sites**															
	5 sites/panel; visit 10 sites per year															
	Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**				
	1	X	X				X	X				X				
	2		X	X				X	X							
	3			X	X				X	X						
	4				X	X				X	X					
	5	X				X	X				X	X				
			not included in the analysis													
	Calculate power after 11 years, based on 4 points															

5.1 General Simulation Protocol

1. Selected a set (number design specific) of site means from the lognormal distribution estimated for X_1, the site mean in year 1 for the given. Randomly assigned sites to panels.
2. Exponentiated the site means to get out of log space. Constructed a series of trended means corresponding to the observed time periods for each panel by adding either 2% or 4% annual linear trend (positive or negative) to the initial site mean generated above.
3. Added random inter-annual error to each annual value in the time series. The errors were drawn from normal distributions with zero mean and with variance estimates described in the Parameter Estimation section above.
4. Estimated the linear regression slope for each site at number of years indicated in Table 1, using the proper year numbers for the x-variable.

5. Conducted a *t*-test of the slopes, and retained the *p*-value.
6. Repeated steps 1-5 for 1000 simulations.

Estimated the statistical power as the percent of the 1000 trials with one-tailed *p*-values less than 0.025 (or 0.05). Note that one-tailed *p*-values are used because a trend detected in the opposite of the added trend would be a type I error, and therefore should not be included as a correct result. The one-tailed 0.025 scenario represents power for a two-tailed test with alpha = 0.05.

6 RESULTS AND DISCUSSION

Estimates of statistical power to detect trend in normalized res idual pool depth over time were made using simulated data. Figures 5 through 13 show samples of some of the s imulated data for Design 1—data were generated using randomly selected means drawn from the estimated mean distribution followed by addition of linear trend and random error. Simulated data for Designs 2, 3, and 4 would look similar and would only vary in the in the years in which data were "observed".

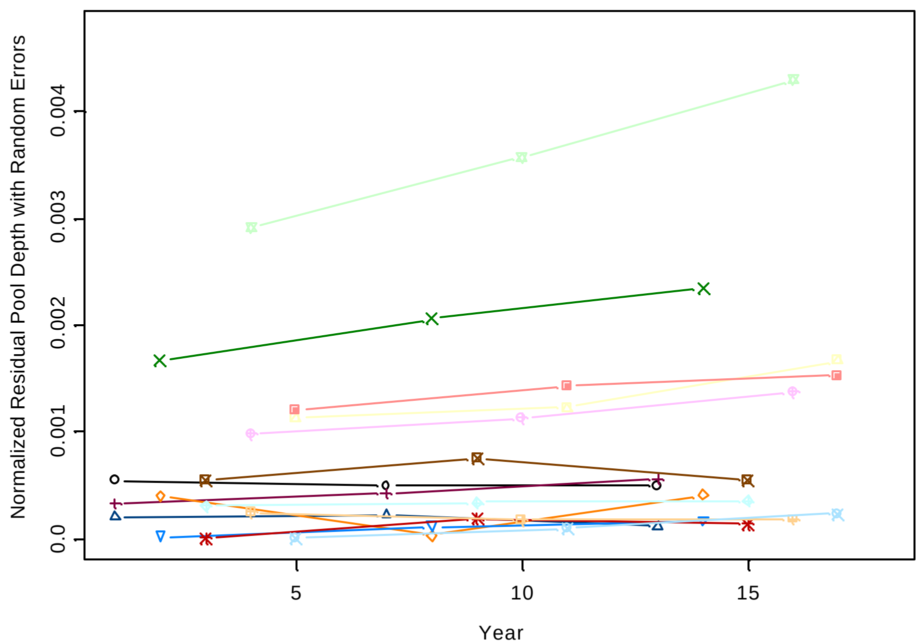

Figure 5. Simulated data for Design 1 including positive 4% annual trend and random errors with the midline standard deviation equal to 0.0001.

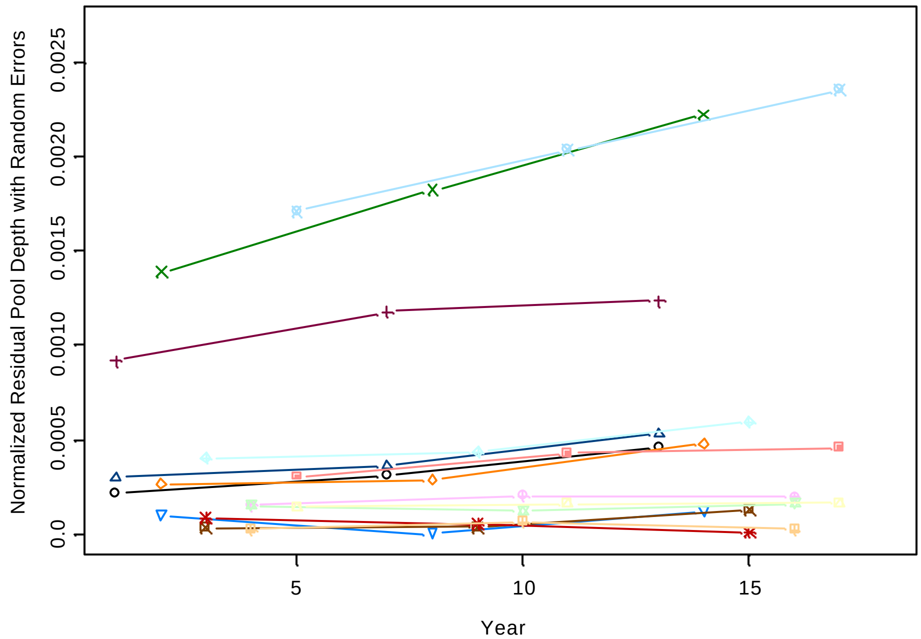

Figure 6. Simulated data for Design 1 including positive 4% annual trend and random errors with the low standard deviation equal to 0.00005.

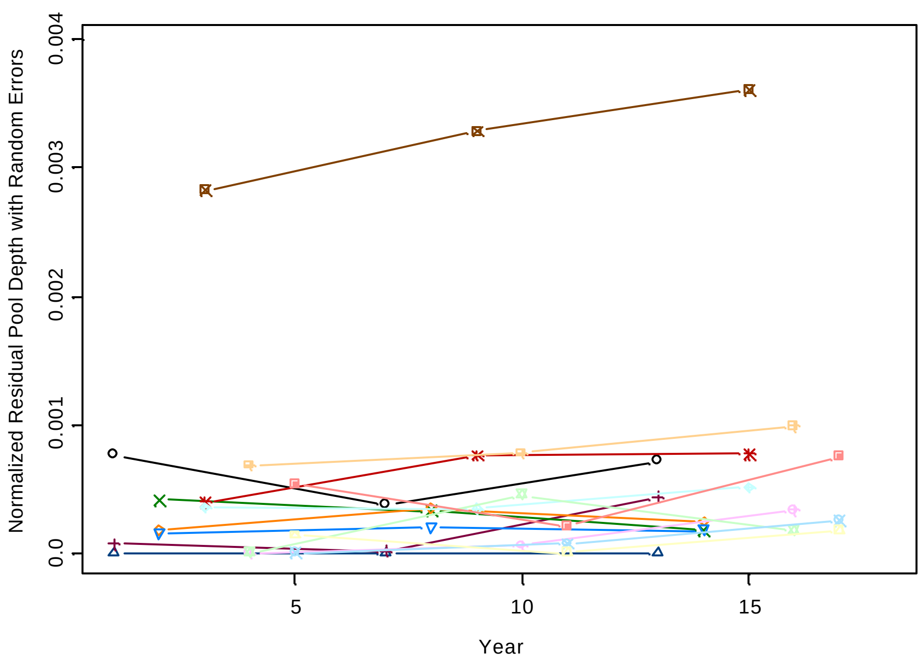

Figure 7. Simulated data for Design 1 including positive 4% annual trend and random errors with the high standard deviation equal to 0.0002.

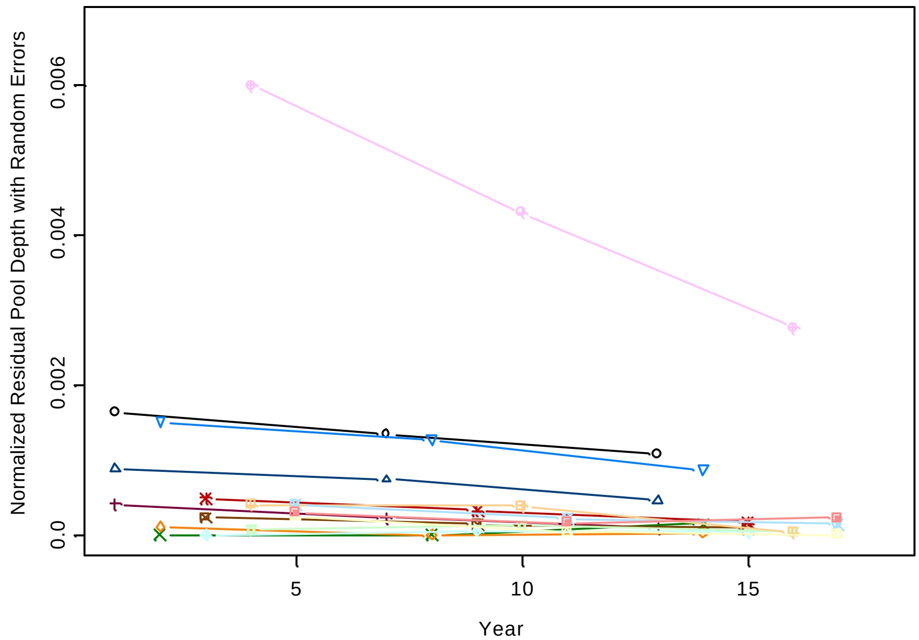

Figure 8. Simulated data for Design 1 including negative 4% annual trend and random errors with the midline standard deviation equal to 0.0001.

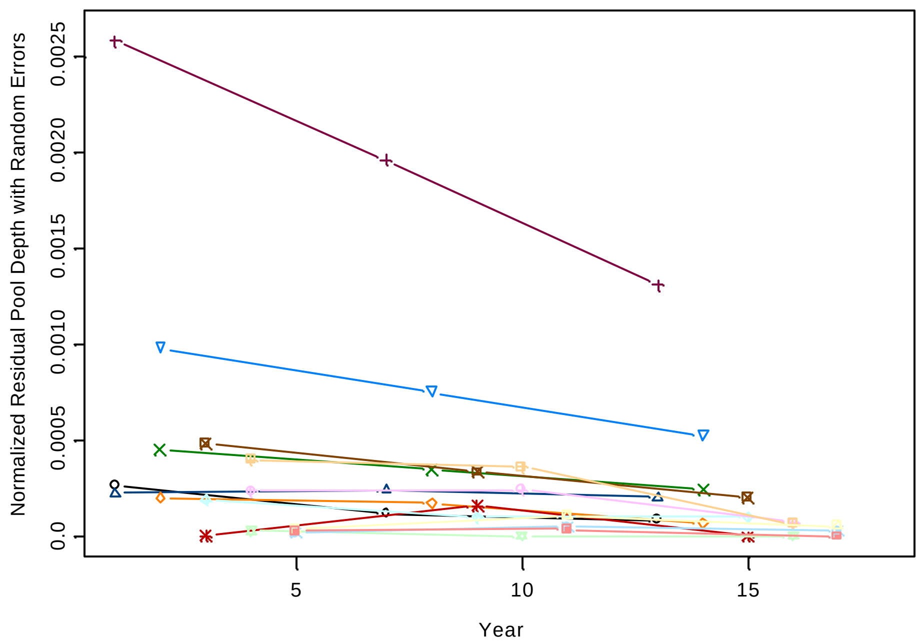

Figure 9. Simulated data for Design 1 including negative 4% annual trend and random errors with the low standard deviation equal to 0.00005.

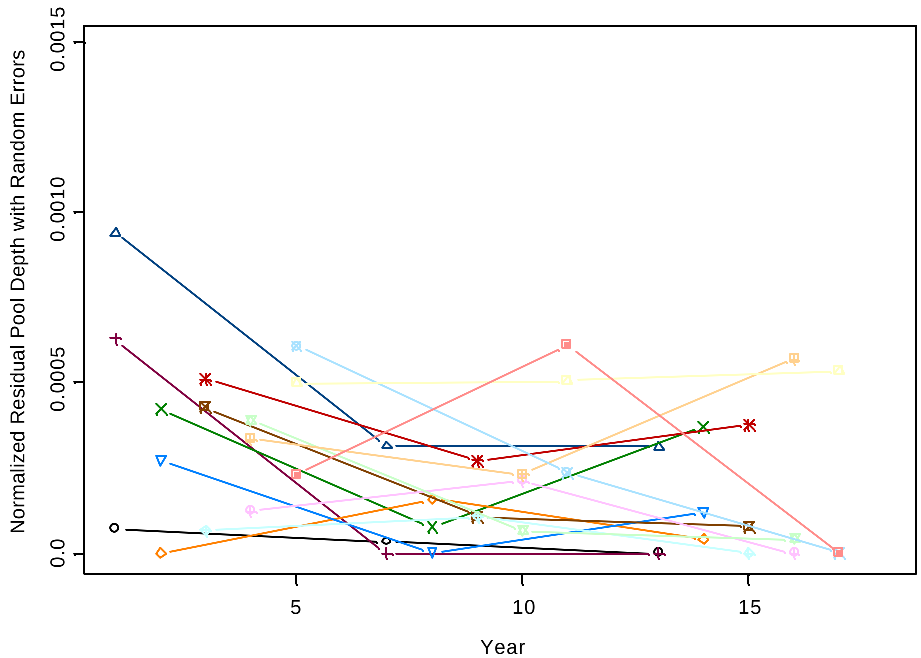

Figure 10. Simulated data for Design 1 including negative 4% annual trend and random errors with the high standard deviation equal to 0.0002.

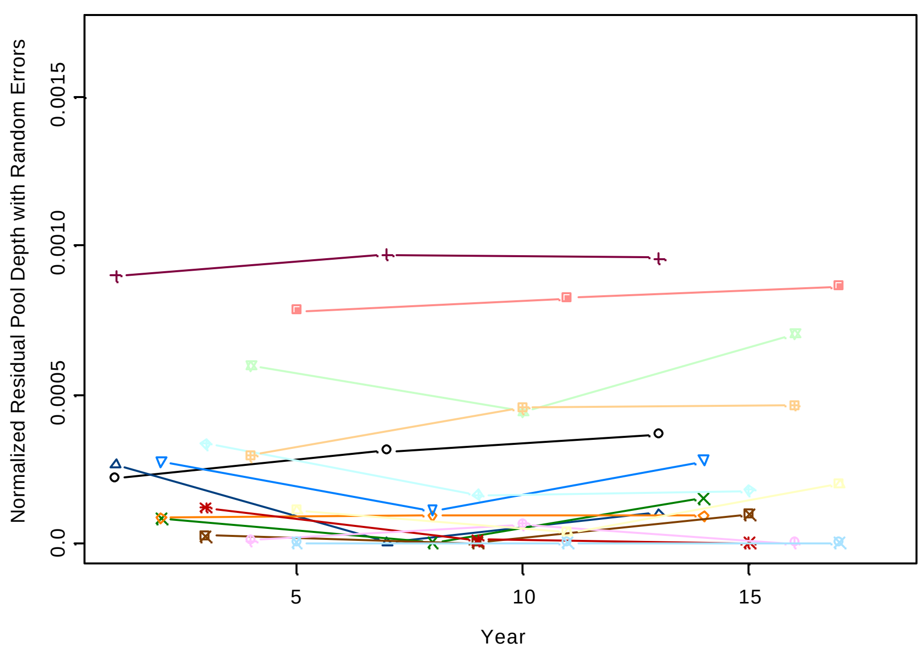

Figure 11. Simulated data for Design 1 including no annual trend and random errors with the midline standard deviation equal to 0.0001.

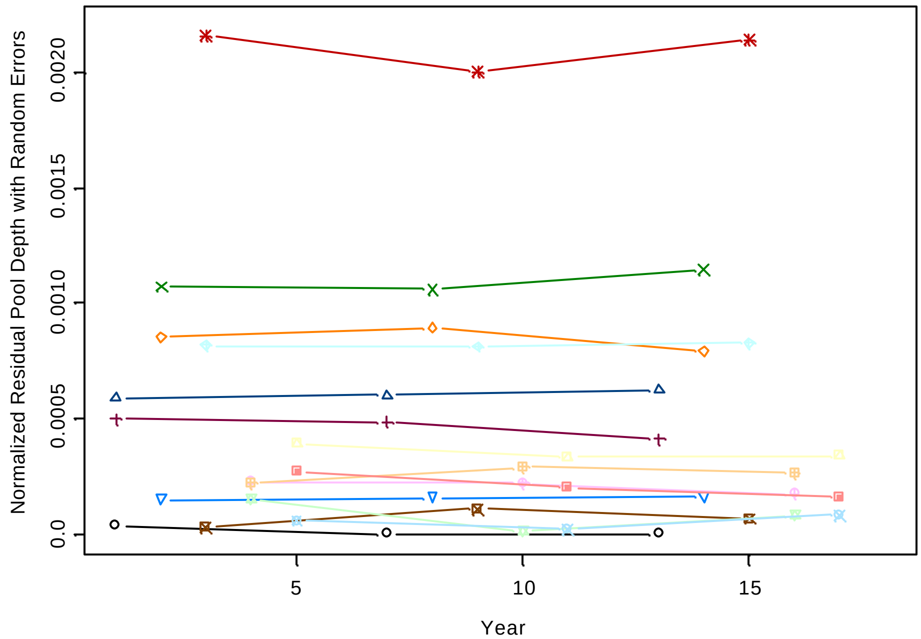

Figure 12. Simulated data for Design 1 including no annual trend and random errors with the low standard deviation equal to 0.00005.

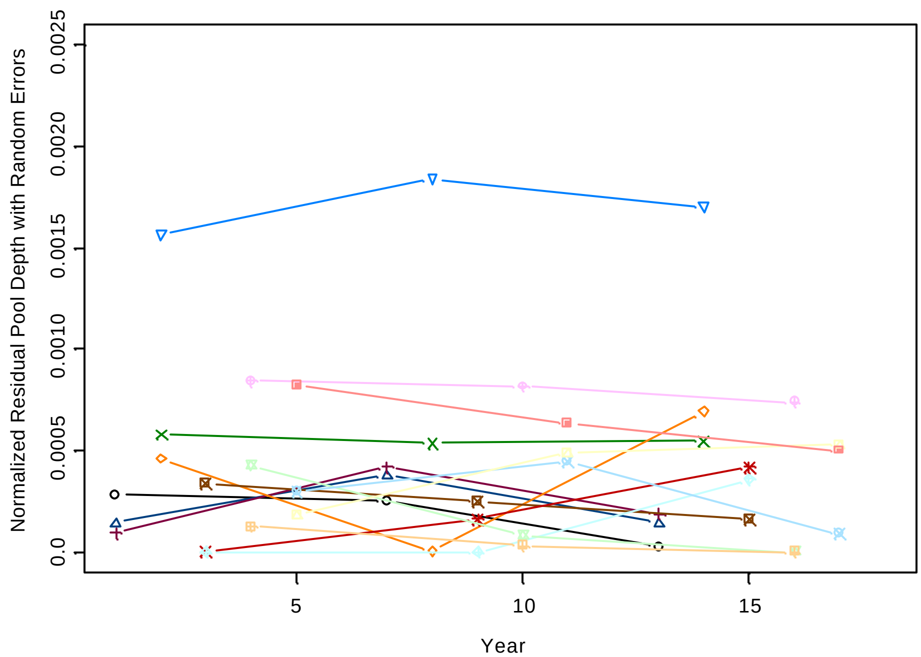

Figure 13. Simulated data for Design 1 including no annual trend and random errors with the high standard deviation equal to 0.0002.

Results from the power analyses based on simulated data are shown in Tables 4 through 7—results for each design are summarized in their own table. All power estimates are based on $a = 0.05$. The reported nominal alpha levels track the Type I error rate (probability of rejecting the null hypothesis that the slopes are equal to zero when the null hypothesis is true), which should be close to 5%.

Table 4. Power estimates and nominal alpha levels for Design 1.

Design 1--Estimated power, alpha = 0.05

	Positive Annual Trend				Negative Annual Trend			
	2%		4%		2%		4%	
Interannual SD	**Year 12**	**Year 18**	**Year 12**	**Year 18**	**Year 12**	**Year 18**	**Year 12**	**Year 18**
0.0001	0.583	0.970	0.969	0.998	0.627	0.964	0.966	0.999
Low--0.0005	0.953	1.000	0.999	1.000	0.962	0.996	0.996	0.995
High--0.0002	0.235	0.588	0.584	0.971	0.223	0.609	0.616	0.964

	Nominal Alpha			
	2% Annual Trend		4% Annual Trend	
Interannual SD	**Year 12**	**Year 18**	**Year 12**	**Year 18**
0.0001	0.043	0.056	0.048	0.051
Low--0.0005	0.047	0.047	0.042	0.048
High--0.0002	0.046	0.047	0.063	0.049

Table 5. Power estimates and nominal alpha levels for Design 2.

Design 2--Estimated power, alpha = 0.05

	Positive Annual Trend						Negative Annual Trend					
	2%			4%			2%			4%		
Interannual SD	**Year 8**	**Year 12**	**Year 16**	**Year 8**	**Year 12**	**Year 16**	**Year 8**	**Year 12**	**Year 16**	**Year 8**	**Year 12**	**Year 16**
0.0001	0.288	0.698	0.937	0.701	0.985	0.999	0.300	0.721	0.948	0.715	0.992	0.997
Low--0.0005	0.696	0.987	0.997	0.986	0.999	0.998	0.728	0.990	1.000	0.983	0.999	0.999
High--0.0002	0.098	0.307	0.564	0.298	0.744	0.956	0.116	0.327	0.588	0.307	0.744	0.949

	Nominal Alpha					
	2% Annual Trend			4% Annual Trend		
Interannual SD	**Year 8**	**Year 12**	**Year 16**	**Year 8**	**Year 12**	**Year 16**
0.0001	0.034	0.056	0.051	0.060	0.047	0.041
Low--0.0005	0.051	0.042	0.040	0.059	0.064	0.046
High--0.0002	0.037	0.047	0.045	0.045	0.050	0.061

Table 6. Power estimates and nominal alpha levels for Design 3.

Design 3--Estimated power, alpha = 0.05

	Positive Annual Trend		Negative Annual Trend	
	2%	4%	2%	4%
Interannual SD	Year 15	Year 15	Year 15	Year 15
0.0001	0.808	0.987	0.788	0.981
Low--0.0005	0.991	0.997	0.983	0.996
High--0.0002	0.357	0.821	0.371	0.791

	Nominal Alpha	
	2% Trend	4% Trend
Interannual SD	Year 15	Year 15
0.0001	0.056	0.051
Low--0.0005	0.048	0.064
High--0.0002	0.045	0.052

Table 7. Power estimates and nominal alpha levels for Design 4.

Design 4--Estimated power, alpha = 0.05

	Positive Annual Trend		Negative Annual Trend	
	2%	4%	2%	4%
Interannual SD	Year 11	Year 11	Year 11	Year 11
0.0001	0.426	0.839	0.456	0.820
Low--0.0005	0.833	0.976	0.837	0.987
High--0.0002	0.174	0.483	0.175	0.432

	Nominal Alpha	
	2% Trend	4% Trend
Interannual SD	Year 11	Year 11
0.0001	0.064	0.046
Low--0.0005	0.058	0.051
High--0.0002	0.064	0.047

The power analyses results show some expected patterns:

- Estimated power to detect trend increases over time. For Designs 1 and 2, power is higher at years 18 and 16 than years 12 and 8, respectively. Likewise, Design 3 shows overall higher power, based on looking at trend after 15 years, when compared with Design 4, which assesses trend after only 11 years. By year 11 or 12 the power estimates are good except for the highest level of variability. By year 18, the estimated power is high for all scenarios.
- Estimated power to detect trend decreases with increasing variability in the random error component. The higher the variability, the more time it takes to detect a statistically significant trend. The lowest variability cases show good power as early as 11 years.
- Estimated power to detect trend 2% annual trends tends to be lower than the power to detect 4% annual trends. Again, the 2% trends can be detected, but more time is required.
- The nominal alpha levels for all designs are as they should be. They sit right around 0.05 when alpha is set at 5%.

6.1 Recommended Panel Design

The survey design must provide a satisfactory balance of data collection that can facilitate both the estimation of status and the detection of trends. In general, incorporating more sample units each year is better for estimating status, while revisiting the same sample units each year better supports trend detection. Of the four proposed panel designs, Designs 3 and 4 are preferred since they are connected designs, meaning that sites are visited two years in a row. This allows for some type of assessment of year-to-year variability within sites. This may be contrasted with the unconnected rotations in Designs 1 and 2.

Designs 3 and 4 give similar results, which are expected since they incorporated the same annual effort (10 sites per year). Estimated power is slightly lower for Design 4 since trend detection is attempted at year 11 as opposed to year 15.

While this analysis allows the relative comparison among the four rotating panel designs, one must remember that these results are only for one endpoint—normalized residual pool depth. Results could be very different for different endpoints. Also, estimates of interannual errors were ad-hoc since the available data lacked time series information. Better interannual error estimates could lead to different estimated power for the residual pool depth endpoint. From a practical point of view, using an analysis based on only one endpoint does not provide enough information as to which design is best. Different endpoints may show more or less variability, which may impact the ability to detect trend.

Based on the analyses that may want to be conducted in the future using data collected from this monitoring program, we recommend using one of the serially alternating designs with consecutive year revisits (Design 3 or 4). The only difference between the designs is the revisit pattern—five years off versus three years off. This difference in revisit patterns translates to different numbers of total sites—35 versus 25 sites. From an estimating status perspective, both designs visit the same number of sites per year. To better satisfy the monitoring status objective, the number of sites per year could be increased depending on budget constraints and practicality considerations. Also, the revisit pattern could be modified to split the difference, four years off instead of three or five years.

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2.0. Site Selection

The sampling scheme involves use of sample sites selected from a "master sample" list generated through the geographic randomized tessellation system (GRTS) currently used by the US EPA EMAP program, as well as the Oregon Department of Fish and Wildlife for their coastal coho sampling scheme. This master sample was generated using a 1:100,000 scale hydrography layer (USGS), with sites randomly selected as intersection points within represented stream systems. This technique results in an order list of potential sampling sites. A complete description of the sampling design and randomized site selection methodology is summarized in Section 1.

This list was further refined by selecting only those sites that fell within stream reaches that had gradient characteristics (< 4%) that correspond to "response" reaches (Montgomery and Buffington 1997, 1998). Response reaches are generally lower gradient, unconfined or moderately confined reaches of streams that are most likely to change in response to inputs of wood, water and sediment. Response reaches are often considered the most biologically active and susceptible to changes associated with increases or decreases in material input processes.

NOTE: The original list of potential sites received from Stillwater Sciences in June 2006 was out of order and site selection was not based on Cedar River Watershed GMUs. This resulted in a high number of rejected sites and site selection out of the intended order.

2.1. Master Sampling List (all years)

Panel Number	GERTS Site No.	Reach Type	Channel Type	GMU	Possible	Site Number
1	56			0	X	1
1	189			0	X	2
1	264			0	X	3
1	242			0	X	4
1	236			0	X	5
2	340			0	X	6
2	102	Response	Plane bed	12	X	7
2	51	Response	Plane bed	13	X	8
2	109			0	X	9
2	291	Response	Plane bed	13	X	10
3	~~5~~			~~0~~	~~X~~	
3	~~8~~	~~Source~~	~~Cascade~~	4	~~X~~	
3	~~10~~	~~Source~~	~~Cascade~~	4	~~X~~	
3	11	Source	Cascade	4	X	11
3	~~26~~	~~Source~~	~~Cascade~~	4	~~X~~	
4	35	Transport	Step-pool	5	X	
4	50	Source	Cascade	4	X	
4	53	Source	Cascade	2	X	
4	63	Source	Cascade	4	X	
4	69			0	X	
5	79	Transport	Step-pool	6	X	

Panel Number	GERTS Site No.	Reach Type	Channel Type	GMU	Possible	Site Number
5	80	Source	Cascade	2	X	
5	85	Source	Cascade	4	X	
5	90	Source	Cascade	4	X	
5	108			0	X	
Additional Sites						
	111	Source	Cascade	4	X	
	113	Transport	Step-pool	5	X	
	116	Source	Cascade	4	X	
	117	Source	Cascade	1	X	
	118	Source	Cascade	4	X	
	129	Transport	Step-pool	6	X	
	137			0	X	
	152			0	X	
	156	Source	Cascade	4	X	
	174	Transport	Step-pool	6	X	
	~~178~~	~~Transport~~	~~Step-pool~~	~~5~~	~~X~~	
	179	Source	Cascade	4	X	12
	~~184~~	~~Transport~~	~~Step-pool~~	~~5~~	~~X~~	
	~~188~~			~~0~~	~~X~~	
	~~192~~	~~Source~~	~~Cascade~~	4	~~X~~	
	~~196~~	~~Source~~	~~Cascade~~	4	~~X~~	
	~~198~~	~~Source~~	~~Cascade~~	4	~~X~~	
	~~206~~	~~Transport~~	~~Step-pool~~	~~5~~	~~X~~	
	208			0	X	13
	~~214~~			~~0~~	~~X~~	
	~~215~~	~~Source~~	~~Cascade~~	4	~~X~~	
	~~221~~	~~Source~~	~~Cascade~~	4	~~X~~	
	224			0	X	14
	~~231~~	~~Transport~~	~~Step-pool~~	~~6~~	~~X~~	
	238			0	X	15
	239	Transport	Step-pool	5	X	
	241			0	X	
	250	Source	Cascade	1	X	
	253	Response	Plane bed	9	X	
	258	Transport	Step-pool	5	X	
	259			0	X	
	260	Source	Cascade	4	X	
	263	Response	Plane bed	9	X	
	267	Source	Cascade	4	X	
	269	Transport	Step-pool	6	X	
	275	Response	Plane bed	9	X	
	283	Transport	Step-pool	6	X	
	287			0	X	

Panel Number	GERTS Site No.	Reach Type	Channel Type	GMU	Possible	Site Number
	290	Source	Cascade	2	X	
	293			0	X	
	303	Source	Cascade	2	X	
	306	Source	Cascade	4	X	
	307			0	X	
	313	Source	Cascade	4	X	
	315	Source	Cascade	3	X	
	320			0	X	
	336			0	X	
	345	Response	Plane bed	10	X	
	348	Transport	Step-pool	5	X	
	349			0	X	
			Total Number of possible Site		**75**	

2.2. Sampling Panel List by Year

File Updated 12/21/07 by AR

Year

Panel	1 (2006)	2 (2007)	3 (2008)	4 (2009)	5 (2010)	6 (2011)	7 (2012)	8 (2013)	9 (2014)	10 (2015)	11 (2016)
1	56, 189, 264, 242, 236*	56, 189, 264, 242, 236*				56, 189, 264, 242, 236*	56, 189, 264, 242, 236*				56, 189, 264, 242, 236*
2		11, 179, 208, 221, 231	11, 179, 208, 221, 231				11, 179, 208, 221, 231	11, 179, 208, 221, 231			
3			35, 50, 53, 63, 69	35, 50, 53, 63, 69				35, 50, 53, 63, 69	35, 50, 53, 63, 69		
4				79, 80, 85, 90, 108	79, 80, 85, 90, 108				79, 80, 85, 90, 108	79, 80, 85, 90, 108	
5	340, 102, 51, 109, 291*				340, 102, 51, 109, 291*	340, 102, 51, 109, 291*				340, 102, 51, 109, 291*	340, 102, 51, 109, 291*

* Panels 1 and 7 where done using Response reach list and are out of order of the master list

2.3. Sampling Design by Year

Panel 1 (List Number and Site number)
56 = 1
189 = 2
264 = 3
242 = 4
236 = 5

Panel 2 (List Number and Site number)
11 = 11
179 = 12
208 = 13
224 = 14
231 = 15

Panel 3 (List Number and Site number)
35 =
50 =
53 =
63 =
69 =

Panel 4 (List Number and Site number)
79 =
80 =
85 =
90 =
108 =

Panel 5 (List Number and Site number)
340 = 6
102 = 7
51 = 8
109 = 9
291 = 10

Section 3: Methodology and Sampling Protocols

3.1. Establishing a LTAM Site

In order to establish a trend monitoring site for this study, a number of criteria must be met (Table 1). If one or more of these criteria are not met, reject the site (see Section 5.1.) and move to the next site on the list. It may take several steps and observations before rejecting or accepting a reach.

Table 1. Criteria for establishment of a LTAM trend monitoring site.

Overall reach gradient is less than 4%
Water is flowing in active channel and is adequate for sampling (not ephemeral or seasonal flow).
Reach length does not cross culverts, bridges, large waterfalls or other obstacles that could interfere with sampling.
Bedrock substrate is not largely acting upon stream flow and sediment transport.
Stream/reach is of a size that can be effectively and safely sampled (e.g., Lower Cedar River is too large).
Stream reach is not affected by other bodies of water or inundation zones that may affect flow and stream processes (e.g., streams affected by Chester Morse Lake).

3.1.1. Reach Layout

A trend monitoring site consists of a unit reach of stream that is a minimum of 40 channel widths (CW) in length. Key locations throughout the reach are bottom of unit (BOU), top of unit (TOU), and three cross-sections (XS), located at approximately 10, 20, and 30 CWs from BOU (Figure 1).

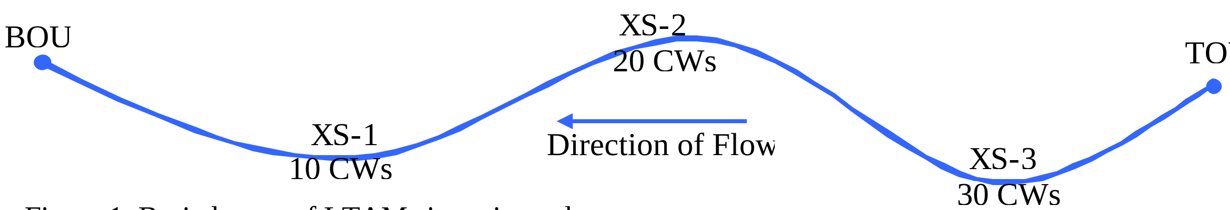

Figure 1. Basic layout of LTAM site unit reach.

BOU and TOU must be located either at the beginning or end of a habitat unit type (e.g., pool head, pool tail) or the transition between sub-habitat units (e.g., glide to riffle transition). Cross-sections must be located in fast water unit types (riffle, rapid) and may cross pocket pools, but not unit pools. Table 2 lists criteria for establishing each XS.

Table 2. Criteria for cross-section establishment.

Fast-water habitat unit (riffle, glide, rapid)
Unit length long enough to accommodate pebble count sampling (see Section 3.4.5.)
Permanent endpoints can be securely established on both banks at relatively the same elevation (see Section 3.3.3.)

3.2. Setting up a Reach

3.2.1. General Order of Reach Set-Up

1. Find GPS coordinate point using GPS unit and/or compass bearing from known point on access road in case that GPS unit is not working well. Flag coordinate point as "Location 1".
2. Measure and record bankfull width (bfw; also referred to as channels widths-CW) and bankfull depth (bfd) measurements to the nearest tenth of a foot.
3. Assess upstream gradient (see Appendix); record in notebook.

4. Based on Location 1 bfw, measure 10 CWs downstream, following thalweg as best as possible. Flag this point as Location 2.
5. Repeat steps 2 and 3 above.
6. Based on Location 2 bfw, measure 10 CWs downstream, following thalweg. If point is not at the beginning or end of a habitat unit, continue downstream until one is reached. Flag this point as Location 3 (tentatively BOU).
7. Return to Location 1 and measure 10 CWs upstream, following thalweg. Flag this point as Location 4.
8. Repeat steps 2 and 3.
9. Average the three bfw measurements taken at Locations 1, 2, and 4; multiply this average by 40 to obtain a total reach length (40 CWs).
10. Subtract the total reach length by the Location 3 (BOU) to Location 4 length. Measure this distance upstream (following thalweg) and flag point as Location 5 (tentatively TOU).
11. Take a weighted average of grade readings (total measured slope height/total measured slope length). Record value.

At this point, if all trend monitoring site criteria are met (Table 1), proceed with step 12. If one or more criteria are not met, go to Section 3.2.2.

12. Distribute locations evenly throughout reach by dividing total reach length by 4. From TOU, measure the adjusted length downstream and assess whether location meets XS criteria (Table 2). If location does meet all criteria, permanently flag as XS 3. If it does not meet XS criteria, move **upstream** either one CW or to the next fast-water unit, whichever is closer. Repeat process until a viable XS can be established.
13. Continue moving downstream to establish XS 2 and XS 1 following procedure in step 11.
14. After permanently flagging BOU, TOU, and all XS, remove temporary 'location' flags to avoid confusion (could also use different colored flagging for temporary and permanent locations).

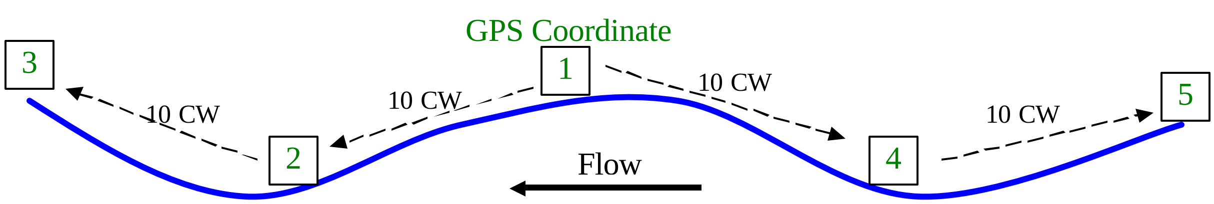

Figure 2. Diagram of reach set-up procedures.

3.2.2. Shifting a Reach

If one or more criteria are not met within original reach, evaluate whether reach can be shifted to avoid problem area. The reach can be shifted up or downstream, however Location 1 (original GPS coordinate point) must remain in the reach. Continue set-up as above, using new locations (see following example). If reach is shifted, record reason for shift, direction of shift, and approximate location of the original GPS coordinate in the new reach. If shifting the reach does not remove problem areas, document the reach as rejected (Section 5.1) and move to next site on list.

Example:
The channel gradient between Location 1 and Location 4 exceeds 4% for greater than 2 CWs in length; however the rest of the reach is less than 4% grade and for 1,000' below Location 3 it is less than 4%. In this case, the reach can be shifted downstream, making Location 1 (or near Location 1 depending on habitat type) TOU and moving the BOU further downstream 20 CWs.

3.3. Permanent Establishment

3.3.1. Labeling

Flagging, aluminum tags, PVC, and trees are all labeled with information about the site and that location. Use permanent black pen on flagging and PVC and secure aluminum tags with either zip ties (on PVC pipe) or small nails (trees).
For PVC pipe over rebar, flagging, and tags label as follows: *"Hydro" "LTAM"" Site #" "Site Name" "XS-#" "Date" "Observer Initials"*
For benchmark and reference trees label: *"Hydro" "LTAM" "Site #" "Site Name" "BM tree or Ref tree #" "Distance and direction to Pin or BOU" "Date" ""Observer Initials"* (Figure 3)

Hydro LTAM Site 1 N. Fork Cedar
BM tree 20' @ 90^{o} 07/01/2006 AM/EM

Figure 3. Example of a labeled aluminum tag on a benchmark tree.

3.3.2. Bottom of Unit (BOU) and Top of Unit (TOU)

The BOU and TOU are both permanently marked with a 5' rebar placed on the left bank (if left bank will not work, put rebar on right bank and note this on the Reach Form). Cover rebar with a painted, labeled, and tagged 5' PVC pipe.

3.3.3. Cross-sections

Cross-section profiles are run perpendicular to the valley floor (rather than the stream) and are anchored by two permanent endpoints. At each XS, measure and record the azimuth of the valley floor (use maps if needed). Shoot perpendicular to valley floor azimuth (90^{o} from) in either direction to establish one XS endpoint, assuring line passes through flagged location. Shoot in the opposite direction to establish the endpoint of the other side. Record compass bearings for each XS in field notebook.

To ensure permanence (or as much permanence as possible), XS endpoints should be placed in a protected area that is relatively safe from flood events, bank erosion, channel migration, tree blowovers, etc. Endpoints must include all active side channels and islands. For reaches with very large floodplains in which set-up and sampling of the XS length is not efficient, endpoints may be placed a minimum of 30' from bankfull. For these cases, reference trees referring to the endpoint need to be established (see 3.3.4.). Bottom line: Choose the best possible long-term location for endpoints while maintaining efficiency in the set-up and sampling of XS profiles.

Cross-section endpoints are permanently marked with one 5' and one 3' rebar. The 5' rebar is pounded in approximately 3' and will serve as the point to attach the tape and mark the endpoint. Place a painted and labeled 5' PVC pipe over rebar to increase visibility. The 3' rebar is pounded in until approximately 2-4" are exposed. This rebar serves as the permanent height "pin." Pin should be placed in front of the 5' rebar (closest to streamside) and as close to marker rebar as possible. Place a rebar cap on each pin.

In cases where it is impossible to use rebar as endpoints (likely because of too hard or too soft substrate), a 'stable' tree (healthy, mature, likely to be around for a long time) can be used as the endpoint if it falls on the XS line. Pound two 6" nails into the tree leaving about 3" out to act as the marker and pin. Bend the marker nail upward to hold steel tape and paint a circle around the pin nail. Tag and flag tree as XS endpoint and note in field notebook.

3.3.4. Reference Trees

Reference trees are used to relocate a permanent XS pin should one be lost. It is best to use a minimum of two trees in order to triangulate pin location. Choose mature, stable trees that are fairly visible from pin. Paint a circle on the tree from which to take distance and compass bearing measurements. Assign each tree a number (use different numbers for all reference trees at the same XS) and record the distance from tree to pin, azimuth from tree to pin, tree species and approximate dbh. Label each reference tree with an aluminum tag and flagging. To increase visibility, paint the tree number on each tree.

3.3.5. Benchmark Tree

Establish a permanent benchmark (BM) near BOU by pounding a 6" nail into a 'stable' tree approximately 2-3' up from the tree base. Leave enough of the nail sticking out from the tree to level the stadia rod against the tree. Flag, paint, and tag tree (paint a circle around the nail). Record tree location (left or right bank) and distance and azimuth from BOU or other permanent reference points (e.g., marked trees) if BOU is difficult to see from benchmark location. Record any other comments that will make relocating tree easier (e.g., on high terrace, near large stump, etc.).

3.3.6. Photo Points

Photos are taken at the BOU (upstream shot), each XS (both upstream and downstream shots), TOU (downstream shot) and any special features such as large dams, changes in slope, etc. At each photo location, record direction (upstream, downstream, right bank looking left, left bank looking right) and azimuth from true north.

3.3.7. GPS

GPS points at BOU (bottom of habitat unit), TOU and at each XS in center of channel (or as near as possible) in line with endpoints. Take a minimum of 30 readings per waypoint.

Throughout field season 2006, we typically took a minimum reading of 100 readings per waypoint and had the Trimble GeoXT unit set at max productivity (high PDOP value). We did not use an external antenna, however it may be useful to use one in the future.

3.4. Sampling Protocols

See Appendix C for published protocols and basic surveying methods.

3.4.1. Cross Section Survey

1. Set up 200 ft steel tape running from Left Bank (LB) to Right Bank (RB) attached to 5' rebar, across channel width. Use clamps on RB to attach tape. Begin Survey on LB pin.
2. Use stadia rod and level. If survey covers large area of floodplain/terrace only one or two measurements are needed to capture length of terraced area. Subsequent measurements should capture distinctive features (bank, bars, bankfull) and instream measurements should capture breaks in slope. Measure where thalweg is located in cross sectional profile.
3. A general rule of thumb is to measure every 1' for streams smaller than 10' BFW, every 2' for streams bigger than 20' BFW.
4. End survey on RB pin.
5. Equipment check is conducted by 1st changing elevation of level (simply lift and re-position/re-level) and then re-reading elevations for RB and LB pin. Compare the difference between the first

LB/RB pin readings and the difference between the second LB/RB pin reading. They should be the same. Maximum difference is 1/100th

Ex: LB pin reading #1 = 1.21 RB pin reading #1= 2.21 = 1.0 difference

LB pin reading #2 = 3.41 RB pin reading #2= 4.42 = 1.01 difference

Difference between 1.01 (Reading #2) and 1.00 (Reading #1) = 0.01 difference OK!

3.4.2. Longitudinal Profile

1. Longitudinal profile measurements are taken while working upstream in the thalweg of the main channel. The thalweg is defined as the line defining the lowest points along the length of a river bed or valley and contain the main flow of water. In cases of split flows, the thalweg is the channel with the most volume of water.
2. To begin, drag the dragline (two tapes spliced together works well) upstream (in thalweg as best as possible) until the 0 on the tape is at BOU. This is most easily done by using TalkAbout radios to communicate while one person drags tape and the other watches the bottom. Securely anchor the upstream end of the tape by tying or taping the line to a large rock or tree branch. Make sure to leave room for tape to follow thalweg in pools and meanders. When the survey reaches the end of the tape, mark the spot where the tape was anchored with a colored marker (painted or flagged rocks work well) and pull the tape upstream until 0 reaches this spot. When doing a tape change, it is *very* important to note "tape change" and how much distance to add in the comments section of the data.
3. To establish a known elevation for the reach, begin the longitudinal profile with an initial reading at the BM tree. Begin in stream surveying at BOU.
4. Horizontal elevation and distance measurements should capture reach changes in the following:
   i. Breaks in unit type (riffle, riffle-steps, glides, etc.)
   ii. Pools (Unit and Pocket pools in thalweg) (see Section 4.4.3)
   iii. Obstacles (glacial erratic, lwd jam, etc.)
   iv. Cross section LB pin (whenever possible, otherwise denote RB pin), taking both an elevation and location along drag line to tie cross section elevation into absolute elevation (BM)
   v. Take notes on location along drag tape of outlet/inlet of side channels, tributaries, split flows, islands, etc.
5. End Survey at TOU

3.4.3 Pool Survey

Conduct pool survey along with longitudinal profile survey. Measure all pools in main channel and any side channels.

1. Determining Unit or Pocket Pool

   Unit pool requirements:
   i. Unit pools must be longer than wide
   ii. Unit pools must meet a minimum residual depth requirement based on the reach's average bfw (Table 3).

   Pocket pool requirements:
   i. Length and width must be 10% of active channel width
   ii. Residual pool depth must be at least 25% of average bankfull depth

Table 3. Minimum Residual Depth Requirements for Unit Pools (WFPB 1997).

Average Reach Bankfull Width	Minimum Residual Pool Depths
0-8 ft	= 0.3 ft
8-17 ft	= 0.7 ft
17-33 ft	= 0.8 ft
33-50 ft	= 1.0 ft
50-66 ft	= 1.2 ft
>66 ft	= 1.3 ft

2. Unit Pools
   i. Numbering: Number unit pools sequentially from BOU upstream.
   ii. Depth: Measure pool depths at tail, max and head using rod and level.
   iii. Dimensions: Length to the nearest tenth foot is captured in longitudinal profile by taking readings along dragline at tail and head of unit pool. Measure the wetted width of the pool to the nearest tenth foot at a location that best represents the pool's average width (typically near mid-point). For especially long pools, average two or three measurements.
   iv. Formation: Record what formed the pool: bank, wood, meander, beaver, tributary, boulder, bedrock, bar, culvert, other human structure, restoration effect, other. If more than one feature is causing the pool to form, record the feature having the most dominant effect and note other features in the comments section.
   v. Pool Type: Plunge, scour, or dammed pool

3. Pocket Pool
   i. Pocket pools are not numbered, but the quadrant they are in is recorded.
   ii. Depth: Pocket pool depths were not measured unless the pocket pool was in the thalweg.
   iii. Dimensions: Measure length and width to the nearest tenth foot with either the stadia rod or logger's tape. Length is measured from pool tail to pool head along the thalweg and width is from basin edge to basin edge.

3.4.4. Large Woody Debris

1. Classifying Woody Debris:

   Individual wood pieces identified as logs must have the following characteristics:
   i. Be dead
   ii. Have root system that is completely or partially detached
   iii. Have a diameter of at least 4 inches (10 cm) for at least 6 feet (2 meters) of its length
   iv. Intrude into the bankfull channel (Zones 1-3)

   Individual wood pieces identified as rootwads must have the following characteristics:
   i. Must be less than 6 feet (2 m) long and have a root system attached to stem
   ii. Must be at least 4 inches (10 cm) in diameter at base of stem
   iii. Roots must be detached from their original position
   iv. Must intrude into the bankfull channel

   Wood accumulations identified as log jams must have the following characteristics:
   i. Have 5 or more qualifying rootwads and/or logs (according to the descriptions shown above)
   ii. At least one qualifying piece intrudes into the bankfull channel

2. Location of LWD pieces in the channel are described with the following criteria (see Figure 5 in the Large Woody Debris Survey Module-TFW Ambient Monitoring Program for a visual description of these zones):

i. Zone 1 is the wetted low flow channel, defined as the submerged area at the time of the survey.
ii. Zone 2 is the area under bankfull elevation and above Zone 1. Exposed bars are located in zone 2.
iii. Zone 3 is the area directly above the bankfull channel- from the projected bankfull flow waterline upwards indefinitely.
iv. Zone 4 is the area outside of the bankfull area. This zone may include upper banks and always includes terraces and floodplains.

3. Inventorying Individual LWD Pieces (not in jams)
   i. Record each single piece of LWD that is at least 6' long and a minimum of 4" in diameter. Tally and describe single woody debris pieces as outlined below. The dominant function should be recorded at the time each piece is tallied.
   ii. Record total length and length in each Zone that piece is in (estimate 4 and measure every 5th piece)
   iii. Record small and large end diameter (estimate 4 and measure every 5th piece)

Rootwad: Rootwad attached?: Yes/No Bole >6 ft. long and 4 in. diam or Bole <6 ft. long and/or 4 in. diam Bole diameter (nearest tenths of feet at breast height)
LWD Dimensions: Piece length is measured using a tape measure or stadia rod, measuring the length of piece within each zone (1-4). Diameters are measured using a tree caliper or a diameter tape. If the rootwad is present, measure diameter at breast height [dbh] (approximately 4.5 feet from the rootwad). Parameters include: Large end diameter (nearest tenths of inches), Small end diameter (nearest tenths of inches), Full length (nearest tenths of feet), and Length (nearest tenths of feet) in each of the four zones (zone 1- in wetted width; zone 2- above wetted width but within bankfull; zone 2- above bankfull but over the activ e channel and within high/terrace banks; and zone 4- on the floodplain/terrace).
Origin: *Placed*: Logs with cut ends placed in stream *Streamside:* LWD (≥6 ft. long and 4 in. diam) recruited from within 6 ft. of the active channel. *Non-streamside:* LWD recruited from hillslope or valley floor surfaces greater than 6 ft. from the active channel. Point of origin is discernible. *Fluvial*: LWD floated into place from upstream. *Unknown:* Undiscernible source of LWD.
Decay Class: 1 through 5 based on presence of bark and twigs, texture, shape and wood color. Based on TFW Ambient Monitoring Protocol (1994)from Robison and Beschta (1991). *Class 1:* Bark- Intact ; Twigs- Present; Texture- Intact; Shape- Round; Wood Color- Original. *Class 2:* Bark- Intact; Twigs- Absent; Texture- Intact; Shape- Round; Wood Color- Original. *Class 3:* Bark- Trace; Twigs - Absent; Texture- Smooth; Shape- Round; Wood Color- Original to darkening. *Class 4:* Bark- Absent; Twigs - Absent; Texture- Abrasion w/ some holes; Shape- Round to oval; Wood Color- Dark. *Class 5:* Bark- Absent; Twigs - Absent; Texture- Vesicular w/ many holes; Shape- Irregular; Wood Color- darkening.

Wood Functions: **POOL TYPE**: LWD contributes to pool formation (where minimum length/width is >10 % of bankfull width, and minimum residual depth is >25% of average bankfull depth. Based on TFW…): *Plunge (step:* The LWD partially spanned the channel, creating a step and resulting in plunging flow. *Flow constriction:* The LWD constrained flow and resulted in bed scour. *Flow deflection:* The LWD deflected flow and resulted in bed scour. *Side/pocket pool:* The LWD resulted in a side or pocket pool that met pool criteria (25 percent of bankfull depth; 10 percent of bankfull width). *None:* The LWD was not forming any pool features. **POOL SIZE**: channel-spanning pool or pocket pool **BAR TYPE:** sediment deposits are adjacent to LWD and have elevated the stream bed *upstream bar:* sediment deposits are on the upstream side of LWD *downstream bar:* sediment deposits are on the downstream side of LWD *lateral bar:* LWD contributes to meander bend sediment deposits *island:* LWD contributes to mid-channel sediment deposits. Split flow occurs at bankfull. *none* **BANK**: *causing bank erosion:* directs streamflow into an unstable bank (exposed soil/substrate, tension cracks, landslides, or slumps above bankfull) and/or has loosened bank material above bankfull *stabilizing bank:* deflects streamflow away from bank and/or has added cohesiveness to bank material *n/a* **WOODY DEBRIS:** *forming logjam:* 5 LWD pieces that touch, whereas each piece is ≥6 ft. long and 4 in. diam *currently trapping small LWD and organic matter:* a minimum 1 ft^2 area of pieces that are <6 ft. long and/or 4 in. diam *none*
Trapping Small LWD and Organic Matter: *Areal extent of small LWD (<6 ft. long and/or 4 in. diam) and organic matter:* all accumulations ≥ 1 ft^2 in area. If an accumulation touches more than one LWD piece, record only once.
Key stability factor (holding wood in place during bankfull flow conditions): *Floodplain:* over 1/3 of length is beyond edge of active channel. *Rootwad:* size and/or structure of root system gives piece increased stability (at bankfull flows). *Root System: has root system still engaged with the bank* *Partially buried in bank:* piece has increased stability due to complete burial of either end or 50% of length in streambank. *Partially buried in substrate:* piece has increased stability due to complete burial of either end or 50% of length in streambed. *Pinned (boulder, trees, bedrock):* piece has increased stability due to having another qualifying piece on top of it or being pegged between other logs, standing trees, or bedrock. *Cabled:* piece has increased stability due to being cabled to nearby stationary elements. *None:* piece has none of the above stabilizing elements.
Age of trees growing on wood: 0, 1-2, 2-5, 5-10, >10

4. Inventorying LWD Jams

A jam is defined as 5 or more qualifying woody debris pieces that touch. Qualifying pieces must fall within the woody debris classes as outlined above. Count and record jams and jam pieces for every unit as outlined below.

i. Jam Number: Number all jams sequentially from BOU upstream.
ii. Measure and Tally pieces in jam:

	Diameter	**Length**	**Measure/Tally**
Large Woody Debris	>36 inches (61cm)	>50 feet (15.25m)	Measure
Medium Woody Debris	>24 inches (61cm)	>50 feet (15.2m)	Measure
Small Woody Debris	>12 inches (30cm)	>25 feet (7.6m)	Tally
Extra Small Woody Debris	>4 inches (10cm)	>6 feet (1.8m)	Tally

iii. Number of Rootwads in jams: Tally each rootwad that is not part of a piece of wood already tallied as Large, Medium, Small, or Extra Small woody debris within the jam.

iv. Jam Function: For each jam, record primary wood function for Pool Type, Pool Size, Bar Type, and Bank. If multiple functions are observed within each category, note those in comments.

3.4.5. Pebble Counts

1. Pebble counts are conducted at each XS for a total of 3 sampling locations. Ideally, pebble counts should be conducted in the same fast habitat type (e.g. riffle or glide, but not both). Pocket pools within riffles are okay to sample, however make a note of which substrate counts were taken from the pocket pool and record pool attributes (length, width, and type). Pebble counts are not conducted in Unit Pools (slow water unit), thus if a unit pool is encountered before the transect is complete the pebble count cannot be conducted. **Make sure to evaluate XS for available riffle to conduct full pebble count!**
2. A minimum of 100 substrate tallies are required for each pebble count location. Count Bankfull to Bankfull, moving upstream and across channel until the minimum of 100 is reached. Pebble counts must end at the end of a channel crossing, regardless of already reaching 100 tallies. Thus, more than 100 tallies are often recorded.
3. Distance between steps as well as distance between cross channel passes of substrate tallies should be 2 x as long as the largest visible substrate (the D84, which is the largest 15% of substrate visible) in the sampling area (e.g. every 2 feet if the largest substrate has an B-axis of 1 ft). Begin tallying substrate one arms length upstream from the XS profile. It is advisable to set-up the XS first to make sure the riffle is long enough to accommodate the number of pebble count transects needed to tally at least 100 particles.

3.4.6. Hobo Temperature Probes

1. Set up Hobo Water Temp in office using HoboWare software. Plug temperature probe into the optic USB base station by aligning the arrow on the probe with the arrow on the base station. Under "Device" choose "Launch". Label the probe by entering the site number and name into description. Check both Temperature and Logger's Battery under Channels to Log and set the logging interval for 1 hour. Launch time can be either started immediately or delayed, depending on when the probe will be deployed. Flag each Hobo with site number and name to avoid confusion with other probes.
2. Hobo probe should be placed near BOU in a pocket pool with a steady flow of water moving through it that is not likely to be de-watered as stream flow decreases. Do not place in a stagnant pool in which stratification may occur. Additionally, avoid deploying probes near seeps, springs, tributaries, backwater areas, or pools greater than 4' deep.
3. Secure probes to a nearby stable tree or branch with nylon rope and duct tape. Leave enough slack in the rope that the probe falls freely, but remains in the pool. To ensure the probe sensor remains in the water, a rock or other weight may need to be attached to the rope near the probe. Duct tape works well for attaching weights.

3.4.7. Site Map

1. Sketch a rough draft of the reach in the field. Include location of benchmark tree, reference trees, and any major features such as large jams, bedrock substrate, etc.
2. In the office, draw the map to scale using longitudinal profile data, field notes, and field map. Include valley and XS azimuth readings, direction of flow, benchmark/reference tree distances and azimuths, side channels and islands, tributary inlets, and any other prominent features. Draw in best access point(s) and, if possible, route from road.

3.4.8. Reach Form

Create a reach form to gather and document observational data on daily discharge, confinement, bankfull widths, bankfull depths, reach type, wildlife observations, weather observations, coordinates, as well best access to site and driving and hiking time.

3.5 Equipment Check List (Excel sheet, printed separately)

3.6 Pre-Field Office Work

Pre-existing site:

1. Print out **Reach Form** and **Notes Form** located at [J:\ssw/ws541\secure\hydrology/monitoring data\long-term aquatic monitoring] in each site folder. These forms contain data on site location, best access, site descriptions, location and azimuth of cross section pins, bottom and top of unit.
2. Bring along copy of **Maps** (large scale watershed map, site map with culverts, sketch map (scans)) located at [J:\ssw/ws541\secure\hydrology/monitoring data\long-term aquatic monitoring\maps\]

New Site:

1. Determine next potential site/s on monitoring points list/panel for your survey year.
2. Enter the latitude and longitude data associated with the list# into GPS unit to determine point location.
3. Create a map of the general location of potential site. By creating a map using lidar and culvert data you can determine best access and approximate location of the site off of the road. It helps to map out several points beforehand so that in instances a site is rejected you can easily move to the next point on the monitoring point list.
4.

3.5. Equipment List by Task

TASK | **EQUIPMENT NEEDED**

General Equipment:

? Rite-in-the-Rain field notebook
? Field vest and pack with compass, Sharpies, pencils
? Orange velcro utility clips
? Trimble GeoXT GPS unit
? Palm Pilot (charged up!) and in SealLine case
? Two SPU radios (low- and highband)
? Two "Talk Abouts" with handsfree ear pieces
? Digital camera
? Map of sites and roads
? Paper data forms (*J:\SSW\WS541\Secure\Hydrology\DataForms*)
? Extra batteries
? Numerous rolls of flagging
? Field first aid kits
? Bug spray, sunscreen
? Duct tape
? Waders and boots
? Gloves, hats, HeatTreats
? Water and lunch

Setting up site:

Gradient assessment

? Abney level, laser RangeFinder, and/or clinometer
? Stadia rod
? Graduated PVC pole of known length (5')
? Hip chain
? Handheld bubble level

Establishing site
(including setting up BOU, TOU, XS, and benchmark and reference trees)

? Hip chain (with extra string)
? Flagging
? Graduated reel tape
? Steel Mallet
? Six 3' rebar
? Eight 5' rebar
? Eight 5' PVC lengths
? Two PVC quivers (for carrying rebar and PVC into site)
? Six LTAM labeled rebar caps
? 15+ Aluminum tags
? 15+ Zip ties or wire
? 1+ 6" nail
? 15+ 1.5" nails
? Orange spray paint

Sampling:

LWD Inventory

? 24" Calipers
? Marking chalk (holder and chalk)
? Logger's tape

Pebble Count

? Two 12" Plastic Rulers (flagged!)

Cross-sectional Profile

? Sokkia Level (calibrated)
? Domed tripod
? Handheld bubble level
? Stadia rod
? 200' Steel tape
? Two metal tape clamps
? Two plastic EZ-Grip clamps

Longitudinal Profile/ Pool Inventory

? Sokkia Level (calibrated)
? Domed tripod
? Handheld bubble level
? Stadia rod
? Plastic dragline tapes 200' and 100' lengths

Additional Equipment:

? ____________________________
? ____________________________
? ____________________________
? ____________________________
? ____________________________
? ____________________________
? ____________________________
? ____________________________
? ____________________________
? ____________________________

Section 4: Specific Site Information

4.1. Year One LTAM Site Map: Sites 1-10

4.2. Time and Personnel Requirements for Field Season 2006

4.3. General notes about 2006 Sites

1. Uniform Pebble Count Method for Sites 1-10.
2. Uniform Wood Survey Method for Sites 1-10.
3. Cross Section Method:
   a. Added “thalweg” measurement for Sites 2, 5, 6, 7, 10.
   b. Changed establishment of pin location from out of floodplain (many times being valley wall to valley wall) to a set distance of 30 ft. from BF (minimum unless there are very stable trees closer, push out as needed based on active side channels, erosion, proximity of better location) for Sites 2, 5, 6, 7. (Established reference trees as needed.)
   c. Re-bar caps available and used on Sites 2, 5, 6, 7, 10.
4. Uniform Profile Method
5. Labeling Method:
   a. Added “Hydro” to flagging label.
   b. Added paint to some Benchmark and Reference Trees.

6. GPS
   a. Sites 1, 3, 4 only BOU GPS point
   b. Sites 2, 5, 6, 7, 8, 9, 10 BOU, TOU, Each XS GPS Points

7. See LTAM Final Methods 2006 for Re/Establishment Methods (i.e. for “lost pin” go to Labels: b. Reference Trees).

4.4. Individual Sites 1-10

Each site in this section includes a map of the site with labeled roads and culverts, the site reach form, all site photos, field notes, and original map sketches.

Section 5: Rejected Sites

5.1. Documenting Rejected Sites

The following should be documented for rejected sites:

1. List #
2. Location
3. Date rejected
4. Reason for rejection
5. Approximate percent grade
6. Estimated bankfull dimensions
7. Confinement (entrenched, moderately entrenched, unentrenched)
8. Morphology
9. Riparian habitat (e.g., mature forest primarily consisting of 12-18” conifers)
10. Additional comments
11. One or more representative photos

Create a Word document with the above information and photos for each field season.

Section 6: Data Management

6.1. Collection

Data is collected in the field using handheld PalmOne devices equipped with Pendragon Forms 5.0. Forms are created using Pendragon Forms Manager 2002 located on the desktop or in program files under the same name.

Forms location: *J:\SSW\WS541\Secure\Hydrology\Pendragon\Long-term Aquatic Monitoring*

Form Names (most current as of 11/2006): Cross Section, LWD_indiv_ltam, LWD_jam_ltam, Pebble Count, Photographs, Pocket Pool_Inventory_ltam, Profile_unit pool_ltam, Reach*

Note: Profile_ltam version was used when doing pool inventory (unit pool) separately from longitudinal profile.

Quick Pendragon Tutorial:

-Select Pendragon Forms Manager.
-Select OK, Select Open, this brings you to the forms manager.

1. Create
   To create a new form select new under "Form Functions". Enter Question (ex: LWD length) under Field Name on Field tab. Select field type (numerical, text, check box, etc.). Be sure to order questions on form in logical sequence for use in field. Under Data tab select "auto-default" for queries that remain constant for a length of time (such as site #, x-s #, etc). Select "required" for values that must be answered for every query.Use Script tab to enter unique commands such as "skip question 5 if value of question 3 is 0"

   This is denoted by the script:

   select:
   if answer = N then
   goto5
   endif

   goto4

2. Edit*
   To edit forms highlight the form name under "Form Designs". If design is frozen select "Copy" This new copy will be editable. Click the copied form and select "Edit". Create new fields. When finished editing recycle old form design and save new 'copied' design under same name (to keep names consistent and avoid longer and longer versions).
   *Note before editing make sure all forms, data, etc. has been "Hot Synched" from palm to computer. By changing a form you are changing its unique identifier number that allows data from your palm to link with data on the Pendragon forms manager. Always Hot Sync first!

3. Backing up forms
   Back up forms in a folder labeled "Pendragon Forms + year". Date stamping forms will help updated forms from being confused with older forms.

6.2. Storage
Upload data from the Palm to the computer after every day data is collected. Uploaded data is initially stored in Pendragon Forms and can be viewed by highlighting the specific form and hitting the "Edit/View" button under 'Data Functions'. From here, export data into an Excel spreadsheet, titling the file with the site #, type of data, and date stamp.
Example: Site 1_pebble count_XS1_120106.xls

All data should be stored in a study specific folder on a network drive. All data from 2006 field season is stored in *J:\SSW\WS541\Secure\Hydrology\Monitoring Data\Long-term Aquatic Monitoring*.

6.3. Analysis
Initial analysis of year one data was performed in Excel 2003. Within each workbook a number of worksheets were created including:
(1) 'Raw'- original data (no changes made, directly imported from Pendragon Forms)
(2) 'Working'- data copied and pasted from 'Raw' then modified and analyzed
(3) 'QA/QC'- data copied and pasted from 'Raw' with highlights and comments of problem data (see 6.4. QA/QC)
(4) 'Pivot Table'- data from 'Working' or 'Raw' that has been analyzed in Pivot Table format
(5) 'Graph'- 'Working' data formatted for ease of graphing (sorted, filtered, etc.)
(6) 'Graph Name (profile, XS-1, etc.) - data from 'Working' in graph format (almost exclusively xy scatter plot)

In the 'Working' worksheet, cells and header titles were color-coded to help ease interpretation. For instance, 'raw' data in the 'working' worksheet has grey header columns and all header columns for analyzed or modified data is in turquoise blue. In the LWD 'working' worksheets, light blue header columns represent English standard values whereas the darker blue header columns refer to metric values.

6.3.1. Pools
The following analyses were calculated from both the unit and pocket pool data. Since unit pools were inventoried concurrently with longitudinal profile in 2006, there is no unit pool-only raw data. Additionally, residual depths for pocket pools were not measured, thus pocket pool volumes and total pool volumes are both minimum volumes.

1. Total pool frequency/100m
2. Total # pools/Average Bankfull width
3. Average residual depth of Unit pool
4. Total Pool Area (all pools) ft^2
5. Total Unit pool area ft^2
6. Total Pocket pool area ft^2
7. Average pool area (all pools) ft^2
8. Average Unit pool area ft^2
9. Average Pocket pool area ft^2
10. Total Minimum Pool volume ft^3
11. Total Unit Pool volume ft^3
12. Total Pocket Pool volume ft^3
13. Average Minimum Pool volume ft^3
14. Average Unit Pool Volume ft^3
15. Average Pocket Pool Volume ft^3

16. % Total pool formed by each element (Wood, Boulder, Meander, Bank, Tributary)
17. % of Wood formed pools created by Scour, Plunge, Dam

6.3.2. LWD

The following wood volume equation was used for all volume calculations in which a large and small end diameter was recorded: $V = \frac{Pi \times (R_1^2 + R_1 R_2 + R_2^2) \times L}{3}$

Both English standard and metric volumes were calculated for all LWD.

Individual LWD (ft^3/m^3)

1. Volume/Zone (1-4) and Full length
2. Volume/100m/Zone (1-4) and Full length
3. Total Individual Wood Volume
4. Piece frequency/100m
5. Piece frequency/quadrant
6. Individual volume/quadrant

LWD Jams (ft^3/m^3)

1. Wood volume for all large and medium-sized wood in a jam/Zone (1-4) and Full length
2. Minimum volume for small and extra-small wood in a jam
3. Individual jam volumes (sum of L, M, S, and XS volumes in a single jam)
4. Total minimum volume of all wood in jams/reach
5. Total minimum volume of all wood in jams/100m
6. Minimum Jam volume/quadrant

All LWD (ft^3/m^3)

Analyzed values for all LWD is summarized in a separate worksheet.

1. Total Minimum Volume (individual and jam)/reach
2. Total Minimum Volume/ 100m
3. Total Minimum Volume/ quadrant

6.3.3. Pebble Count

Use pebble count data analyzer form located at:
J:\SSW\WS541\Secure\Hydrology\DataAnalyzers\ SizeClassPebbles102202 (Master) or
J:\SSW\WS541\Secure\Hydrology\Monitoring Data\Long-term Aquatic Monitoring\ Pebble Count Analyzer (Formatted)

6.3.4. Temperature

While the HoboWare software provides some analysis of temperature data, import data into an Excel spreadsheet to analyze and graph the following:

1. Seven day maximum temperature moving average
2. Daily maximum temperature
3. Daily minimum temperature
4. Daily average temperature

6.3.5. Cross-Section Profile

The first step in analyzing cross-section data is to synchronize readings to the same relative elevation by adding in any backsight readings. Cross-section pin readings from the longitudinal profile survey can then be used to calculate a relative reach height for each cross-section. Cross-section distance readings may also need to be adjusted if more than one length of tape was used.

The second step is to graph each XS profile in an xy scatter plot. Certain line colors or markers can be used to show instream readings, bankfull heights, thalweg, features of interest, etc.

6.3.6. Longitudinal Profile

Similar to cross-section profile analysis, height and distance readings from longitudinal profile data need to be adjusted by adding backsights (calculated height) and tape lengths, respectively. The benchmark elevation (set to 100' for all 2006 survey) is used as a relative elevation to convert calculated stadia readings to relative elevations. Graph adjusted data in a xy scatter plot with backsights and cross-section pin heights removed from the data range (graph cross-section pin heights independent of instream data). Use different line colors and markers to represent specific features such as unit pools, bedrock substrate, LWD jams, etc.

6.4. Quality Assurance/Quality Control

QA/QC should be done for all data and information collected. On the "Raw Data" worksheet, highlight in yellow any cells/values that are missing, negative, or 'wrong' in some way. 'Wrong' data may be unit pools that are wider than long, lwd small diameters that are greater than the large diameters, gaps in data, etc. Looking at the data both numerically and visually can help identify wrong values.

Copy all rows with highlighted cells in "Raw" and paste into a separate "QA/QC" worksheet (also copy the header rows). Insert two more columns to "QA/QC" titled 'Raw Row' and 'Data' (raw row is the row numbers from the raw sheet that correspond with each copied row and data refers to whether the data is original or revised).

In the QA/QC rows, insert a comment for each highlighted cell explaining the problem (original data). Create a copy of the original row below it and highlight the change in green with a comment of how the problem was solved (QA/QC data) (Figure 4). In the "Working Data" worksheet, make the appropriate changes to any revised data and insert a comment stating that the value was revised.

Problem: Large end less than small end

Raw Row	Data	UserName	TimeStamp	Site	LargeEndDiamIn	SmallEndDiamIn
4	Original	mccaula	7/27/2006 15:21	3	15	18
4	QA/QC	mccaula	7/27/2006 15:21	3	18	15

Solution: reversed large and small end values

Figure 4. Example of a QA/QC sheet in a LWD Individual workbook.