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Using Stream Geomorphic Characteristics as a Long-term Monitoring Tool to Assess Watershed Function

A Workshop

Co-Sponsored by

Fish, Farm, Forests, and Farms Communities Forum; Simpson Timber Company; National Marine Fisheries Service; Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program.

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Workshop Introduction by Gary Rynearson, Chairman of the FFFC Policy Committee

The Fish, Forests, and Farms Community (FFFC) was formed to address land management and fisheries issues related to the ESA listing of coho salmon (and other salmonid species) in California. The FFFC is comprised of resource based industry representatives including timber companies, farmers, ranchers, gravel extractors, sport and commercial fishermen, and stream restorationists. The FFFC Technical Committee also includes biologists from state and federal agencies and Humboldt State University. An entity such as the FFFC was necessary to address issues related to land use and coho salmon populations in coastal watersheds because these watersheds are predominately privately owned and account for a majority of coho salmon production in California.

The FFFC has three primary goals: 1) to facilitate the recovery of salmon and steelhead stocks in California, 2) to implement recovery measures voluntarily and proactively in cooperation with state and federal agencies based on the best available scientific evidence, and 3) to work towards those recovery programs which are the most cost-effective and promote ecological, economical, and societal stability.

The FFFC has several committees, each formed to address specific needs of the group as a whole. The Technical Committee and the Sampling Committee (a further sub-division of the Technical Committee) have two main responsibilities: 1) promoting research projects to improve the scientific knowledge regarding salmonid life histories and habitat requirements in coastal watersheds and 2) developing (or adopting) standardized protocols for biological and physical assessment and monitoring of anadromous fish habitat and populations in coastal watersheds.

To date, the FFFC Technical Committee has adopted protocols for:
1. channel and habitat typing,
2. inventorying instream and riparian zone LWD,
3. sediment sampling for spawning gravel quality,
4. monitoring of summer water temperature,
5. macroinvertebrate sampling,
6. carcass and redd count surveying,
7. estimating summer populations of young-of-the-year coho salmon and 1+ and 2+ juvenile steelhead,
8. collecting fish tissue samples for genetic research,
9. trapping of out-migrant salmonid smolts, and
10. long-term monitoring of stream geomorphic characteristics.

The purpose of this two-day workshop was to examine and discuss the recently drafted long-term channel monitoring protocol. This protocol was initially developed by Bill Trush for Simpson Timber Company as a potential adaptive management tool for use in the company's aquatic habitat conservation plan (HCP). Since its initial use by Simpson in 1995, the original methods were modified to both expedite data collection and statistical analyses. The FFFC Technical

Committee recently funded a re-drafting of the methods to reflect these changes. The committee also discussed the need to strengthen long-term monitoring objectives as well as gather input from watershed experts on how data would assist in adaptive management. The discussion led to the idea of holding this workshop to gather experts in the geomorphic sciences to discuss related research and to assist the FFFC in strengthening the field methods and analyses of channel monitoring data. This was an opportunity to critically examine the methods and limitations of this protocol, and provide suggestions on other types of watershed monitoring to complement the channel monitoring protocol.

The format of the two-day workshop is as follows:

Day One: Channel processes and function; monitoring objectives; theory behind monitoring; methodologies and protocol; and data analyses.

Day Two: Overview of the use of channel monitoring in land management (five case studies) and a panel discussion based on questions formulated by panel members and those posed by the audience.

Channel Processes and Watershed Function

Tom Lisle, U.S.Geological Survey Biological Resources Division

Introduction

Purpose of this presentation is to put channel monitoring in context of channel processes and dispel the myth of the learned sage walking up the stream channel observing changes in the channel and extrapolating how these changes came about without looking at the rest of the watershed. The message I want to convey is it is not only O.K. to peek at the rest of the watershed, but it is necessary to understand why change has occurred. Many of the other speakers over the next two days will probably reiterate this same point, again and again.

Knowledge of the history and ongoing trends in the contribution of watershed products (water, sediment, woody debris, heat, and nutrients) is essential to effectively monitor and interpret channel condition for adaptive management.

Figure 1: Land-use activities affect downstream resources by changing on-site conditions (e.g., vegetative cover, soil compaction) which change the mobility and availability of watershed products (water, sediment, organic material such as woody debris, nutrients, and heat). The 'watershed product' paradigm simplifies cumulative effects analysis because the effects of a wide variety of activities affecting a wide variety of resources act through the mobilization and transport of only five quantities, and in many cases some of these can be ignored as being unimportant. Effects of land use are transmitted by altered transport and storage of material downstream. Altered inputs of watershed products through the channel system affect channel processes and conditions, and finally, these changes affect downstream resources (e.g., fish populations, water supply). Channel monitoring occurs near the end of this sequence of

cascading processes, and understanding cause-and-effect relations in channels requires an understanding of up-network and up-slope processes as they are arrayed in each watershed.

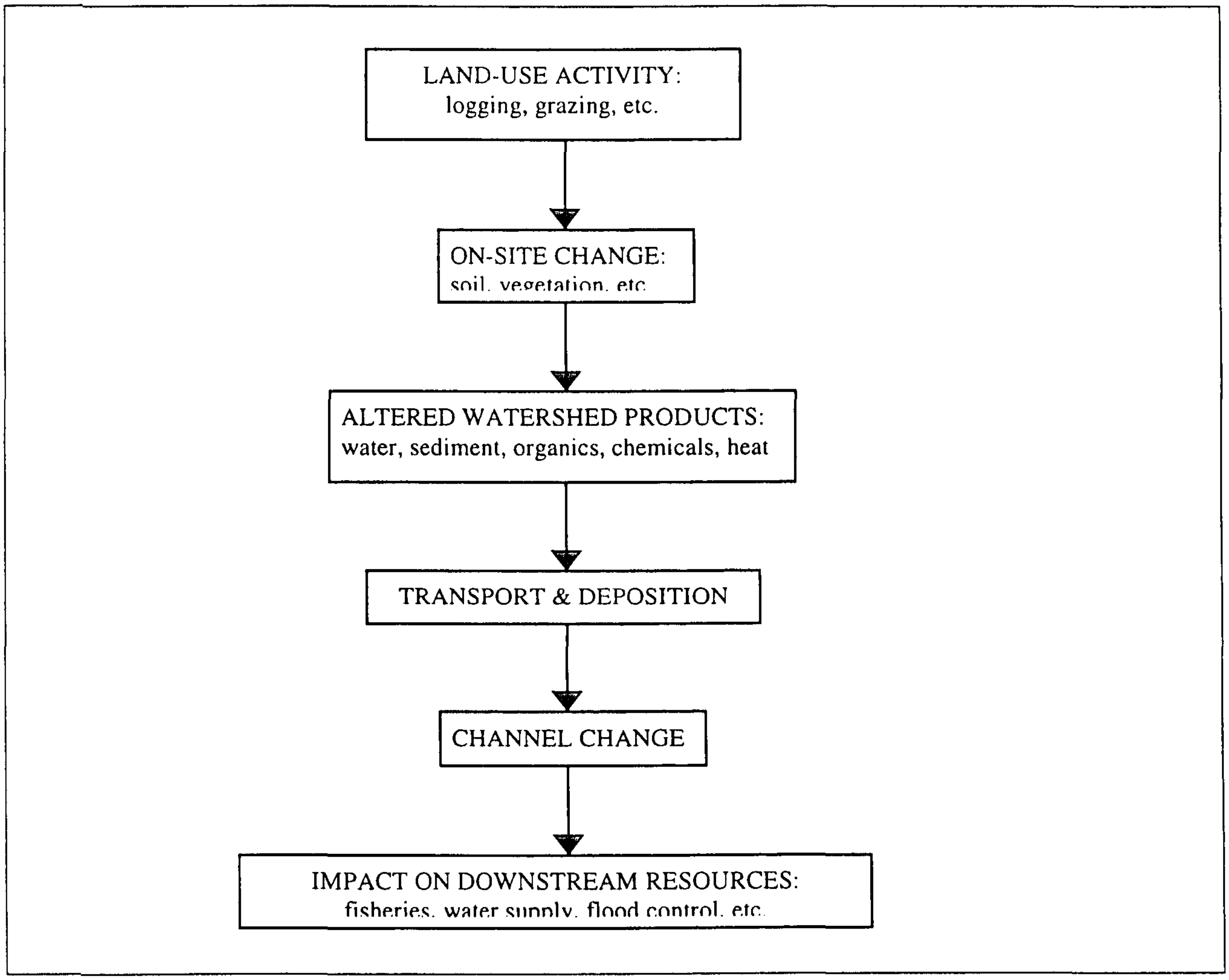

Figure 1. Simplified schematic of the flow of watershed products.

Figure 2: In each watershed, the propagation and ultimate effects of the disturbance of watershed products by land-use practices are uniquely determined by how, when, and where supplies of watershed products are changed, how, when, and where the altered supplies interact and affect channels, and ultimately, how, when, and where downstream resources (e.g., salmon) are affected. Watershed analysis is the process of learning these relations and is the framework for adaptive management. Channel monitoring is just one of the strategies to build more information into an evolving watershed analysis. Therefore, to be useful, any measure of channel condition or process requires putting the channel in context with its watershed. The purpose of this presentation is to further explain why and how this is done.

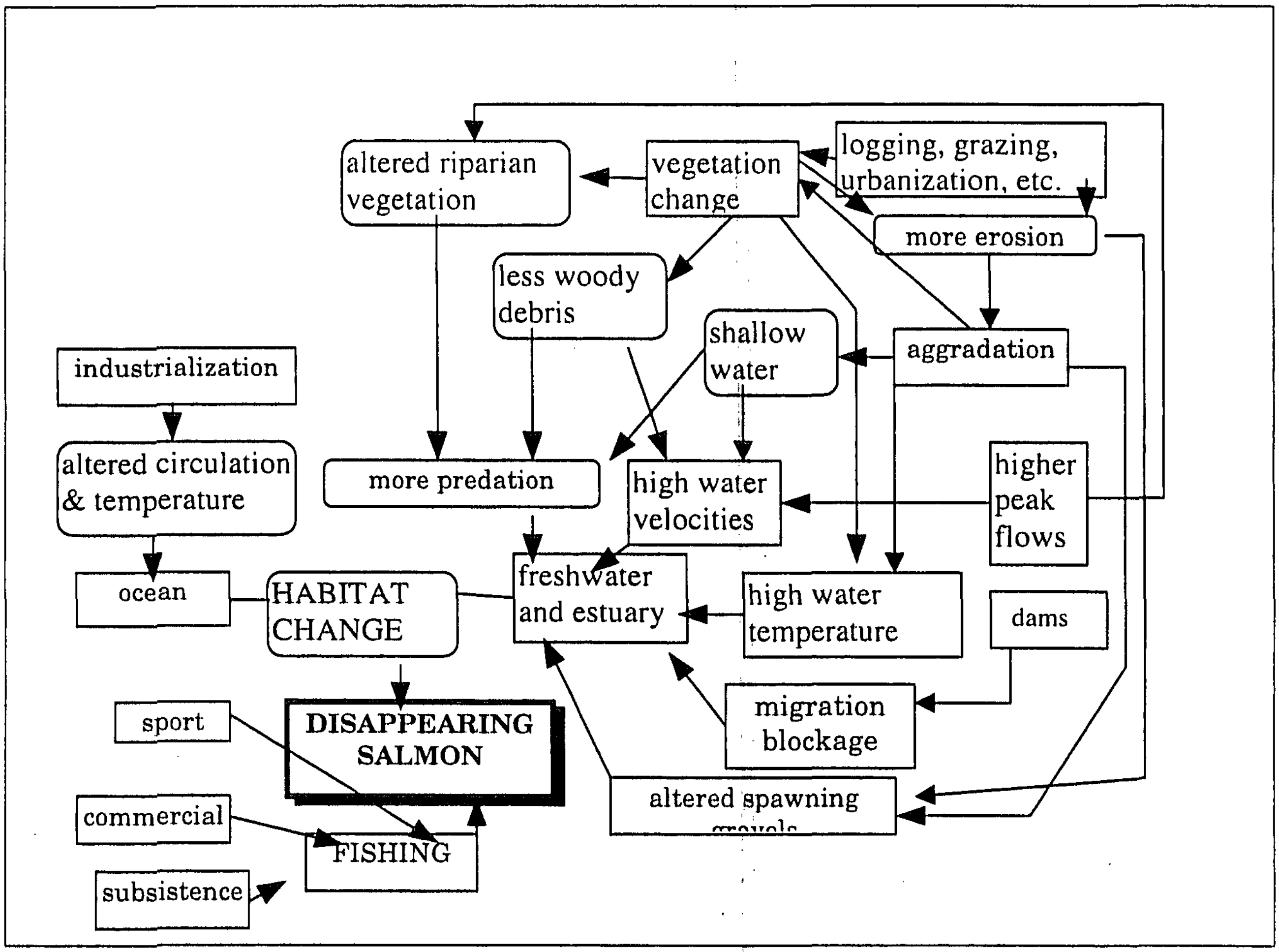

Figure 2. Disappearing salmon, detailed pathway of the flow of watershed products (courtesy of Leslie Reid).

Lags

There are long lags between hillslope disturbance, mobilization and routing of watershed products (particularly sediment and woody debris), and channel response. Climatic events that trigger processes with high thresholds (e.g., landslides, wind throw) may recur only once a decade or so, on average. Therefore, land-use practices that accelerate these processes could accumulate over a long period before their effects become suddenly evident. Other processes (e.g., downstream movement of bed load) occur annually but slowly, producing a long lag between mobilization of watershed products and their appearance far downstream. Monitoring hillslopes and headwaters provides a proactive strategy to correct damaging land-use practices before they impact downstream resources.

Some of the watershed products with the smallest lags between up-slope or up-network disturbance and appearance in the channel include fine sediment (clay to sand), water temperature, and runoff. Channel monitoring of these products can yield timely information.

Indeterminacy of Channel Changes

Knowledge of watershed processes is necessary to determine causes for channel change. Conclusive evidence cannot be found on the victim alone; the same channel change can result from a number of causes related to changes in the supply of watershed products.

In the following two examples, I examine some common linkages between logging and road building and pool habitat, realizing that other activities can ultimately affect pools, and that other factors besides pools are important to fish populations. Logging commonly increases the supply of sediment which can fill pools. However, logging can also increase or decrease the supply of large woody debris, which is commonly responsible for forming many of the pools in forest channels. An interesting interaction occurs between sediment and wood: besides promoting local scour (and forming pools), large wood and other obstructions extract energy from the flow and thereby increase deposition of bed material. Given opposite and interacting effects of wood and sediment, if you increase or decrease supplies of both sediment and large wood in a channel, how does pool volume respond? Two examples are provided:

Figure 3: North Fork Caspar Creek

In an ongoing watershed experiment (Ziemer, 1998), modest increases of sediment and large increases of large wood have affected sediment storage and pool volume in the main stem of North Caspar Creek, Mendocino County, California. Following clear-cut logging of 50% of the watershed and minimal road building in 1989-1991, suspended sediment yield increased by approximately 90%, but no major landslides have occurred (Lewis, 1998). Approximately 1000 Mg of sediment has accumulated in the channel, but this is most likely due not to an over-supply of sediment, but from an increase in storage potential created by a 50% increase in woody debris volume in the lower 600 m of the channel (Lisle, 1998). The new wood came from extensive wind throw from a buffer strip that was left from the logging (Reid and Hilton, 1998). Measured changes in bed elevation at surveyed cross sections was highly variable. Most of the aggradation occurred upstream of new log jams. The increase in wood (along with the increased sediment storage) resulted in a doubling of pool volume.

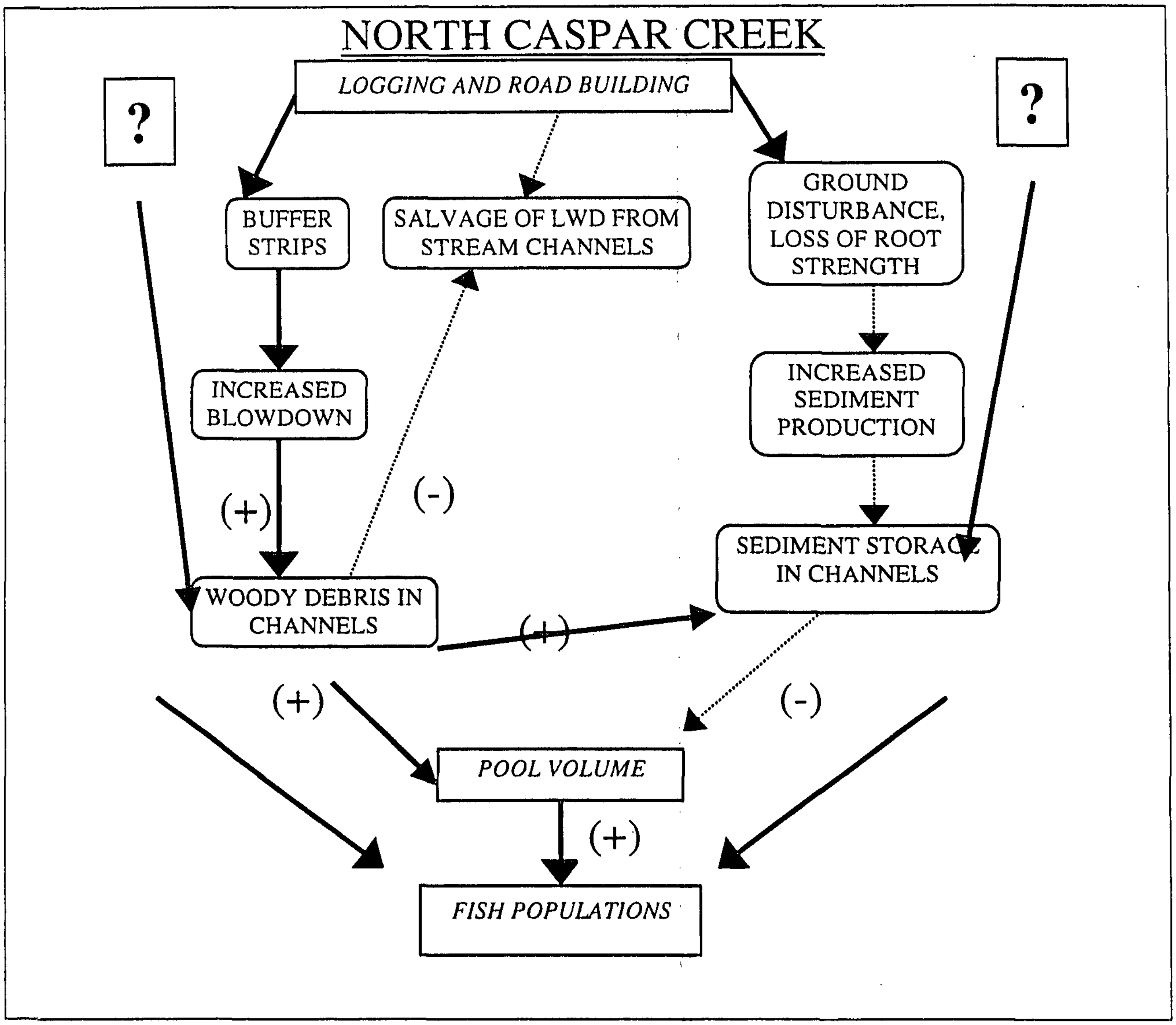

Figure 3. Simplified schematic of the effects of logging and road building on pool volume and fish populations in North Fork Caspar Creek, California.

Figure 4: Mt. St. Helens

The 1980 eruption of Mt. St. Helens, Washington, contributed vast quantities of fine sediment and large wood to channels draining the blast area. Timber companies and Gifford Pinchot National Forest responded by salvaging downed wood from stream channels and hillslopes. The logic of removing wood from channels was that it would hasten recovery of aquatic ecosystems by increasing transport of fine sediment. A group of Forest Service researchers tested this strategy with an experiment whereby wood was left in some reaches of Clearwater Creek and removed from others. Channel cross sections and thalweg profiles surveyed from 1982-1990 show that land managers correctly predicted that removal of wood would reduce storage of fine sediment (Lisle, 1995). However, it also decreased pool volume: Deep and frequent pools

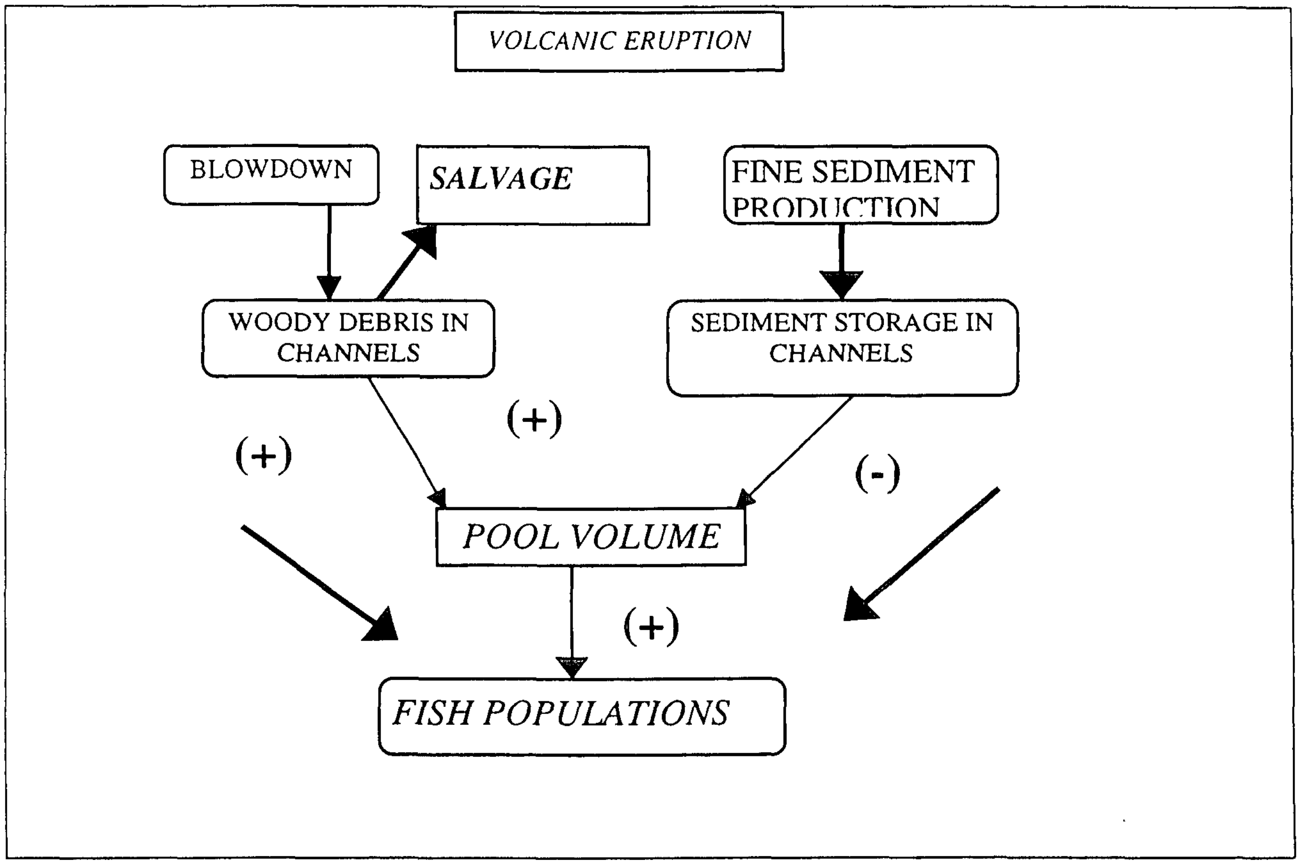

Figure 4. Simplified schematic of the effects of volcanic eruption and salvage logging on pool volume and fish populations following Mount Saint Helen's eruption in Washington.

persisted in channels where wood was retained, and filled where wood was salvaged. The protected reaches contained more sediment and more pool habitat. Salvaging wood defeated the purpose of recovering habitat by removing the predominant factor forming pools, and new supplies of wood to replace that produced by the eruption will not be standing along streambanks for many decades.

Therefore, as in Caspar Creek, pool volume was affected more by changes in the supply of large wood than by changes in the supply of sediment. In order to understand the effects of land use on pool volume and channel elevation, you needed to know changes in the supply of large wood and sediment and to understand their interaction.

Variability of Channel Parameters

Watershed history is necessary to evaluate the departure of channel condition parameters from pristine or reference values. I illustrate this by comparing regional variations in large woody debris volumes in channels.

Figure 5: Cumulative frequency curves of large woody debris volumes (m^3 per ha of channel area) in channels in unmanaged basins are used to show variation within and between forested regions of California and Oregon (Keller and Tally, 1979; Harmon et al., 1986; Berg et al., 1998). Each point along these lines shows the fraction of channels that have less than the wood loading for that point; the median value has a cumulative fraction of 0.5. There are wide differences between regions. For example, median loading for old-growth redwood is about 1000 m^3/ha, while median loading in the northern Sierra Nevada is only 30 m^3/ha. There are also wide variations with regions; the difference between maximum and minimum loadings are well over ten-fold. This indicates that reference (or pristine) loadings for one region cannot be applied to another.

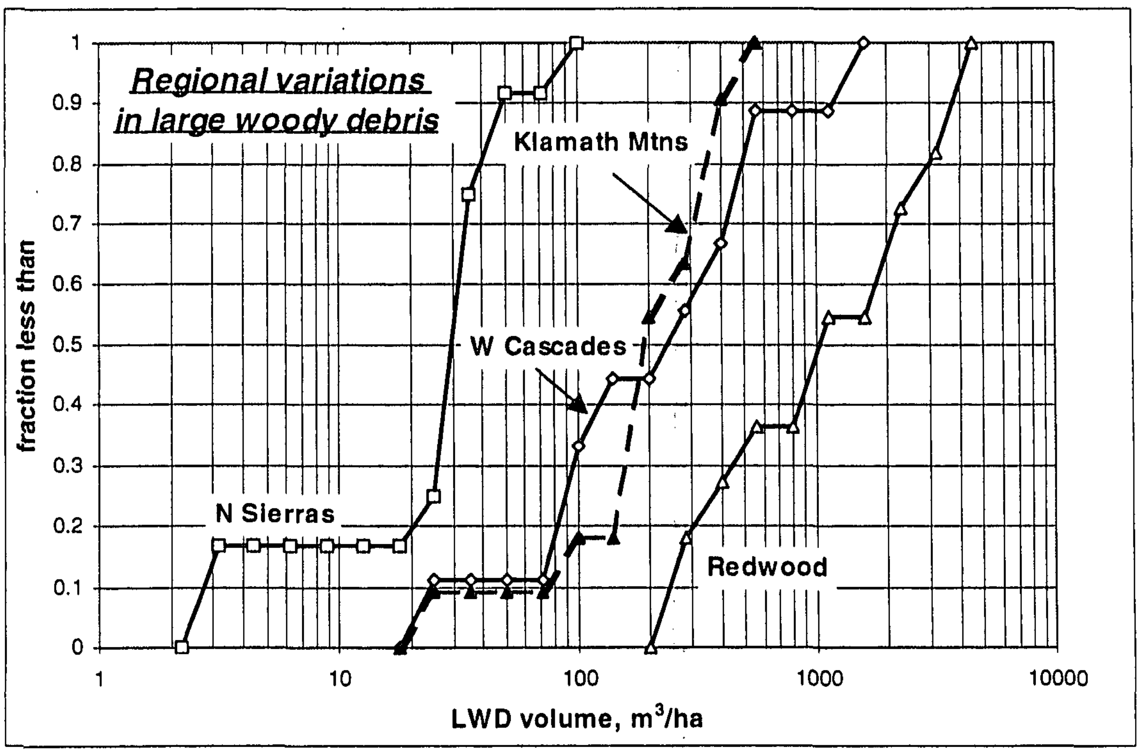

Figure 5. Regional variations in LWD loading in streams within unmanaged watersheds

Figure 6: Second-growth redwood channels contain three to five times less, on average, than old-growth channels (second-growth data from Knoll, 1993). A history of logging, salvage, and stream cleaning has apparently created a deficit of wood in second-growth channels (as well as a decrease in size of pieces). However, as is common with environmental parameters, the distributions overlap. Therefore, although there is a clear departure of wood loading at the

regional scale, the value of this comparison to evaluate appropriate loading for an individual channel is limited. For example, using a 'range of variability' strategy might suggest loadings of 100 m^3/ha would be adequate since such low loadings are represented in at least one old-growth channel. However, such a prescription for the Forest Practice Rules would be likely to worsen the deficit in wood loading on a regional scale. On the other hand, a prescription of the median old-growth loading (1000 m^3/ha) might substantially improve the regional deficit, but many channels would probably always be in violation since one-half of the pristine channels have not achieved this loading. A single-valued prescription for woody debris loading is thus untenable. Instead, target values must be determined with a site-by-site evaluation. This can be done by first comparing measured loadings with regional distributions to gain a crude idea of departures from regional norms. From there, wood in the channel must be put in context with wood in the watershed, as outlined below.

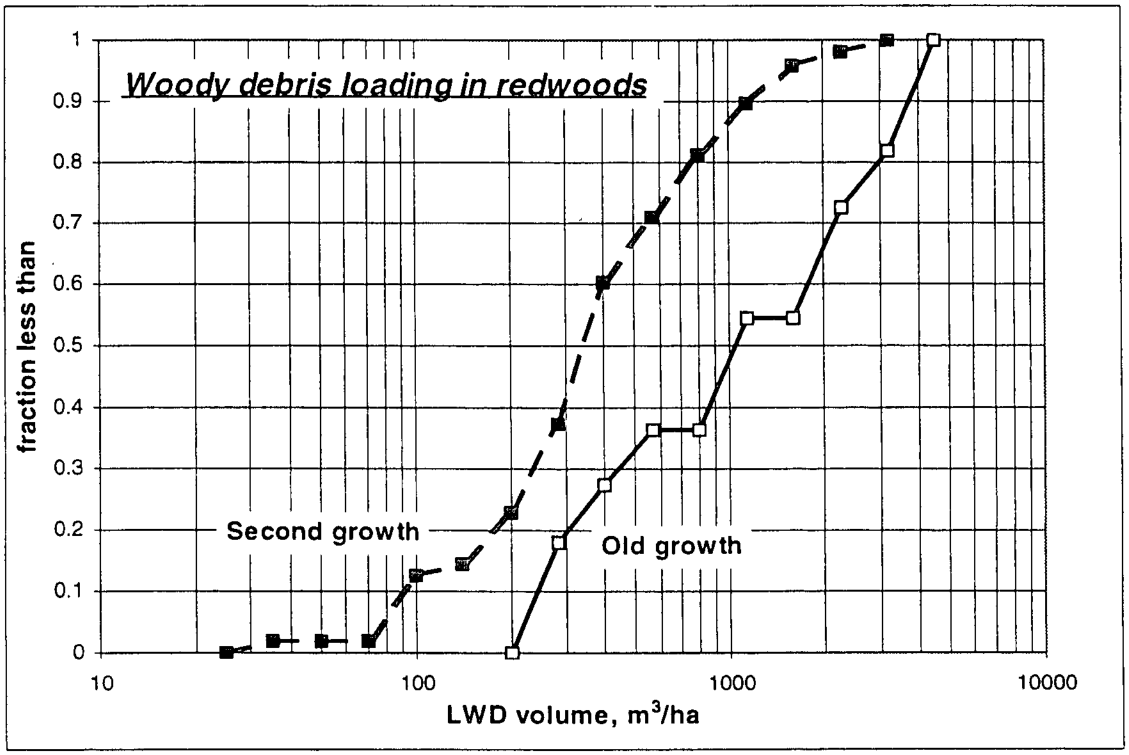

Figure 6. Variation of LWD loading in streams within managed and unmanaged watersheds located in the redwood region of northern California.

Figure 7: In order to evaluate the appropriate wood loading for a particular channel, one must know the history of processes (inputs and outputs) that have culminated in the present loading and will determine the variability of future loadings, given projected land uses. This essentially involves constructing a wood budget, as is done for sediment budgets (Reid and Dunne, 1996). Although values for volumes of wood lost or gained usually cannot be determined precisely, enough can be learned to evaluate important historic trends and thus inform managers to

intelligently evaluate how projected trends would be affected by alternative land use plans. For example, if there has been a history of wood depletion from log runs in the 19th century, followed by aggressive stream cleaning in the 1970's, then there would be added incentive to maintain recovering supplies in intact second-growth riparian stands. In this case, wind throw from narrow buffer strips might provide short-term increases in wood, but early cashing in of remaining wood supplies could perpetuate the deficit in decades hence.

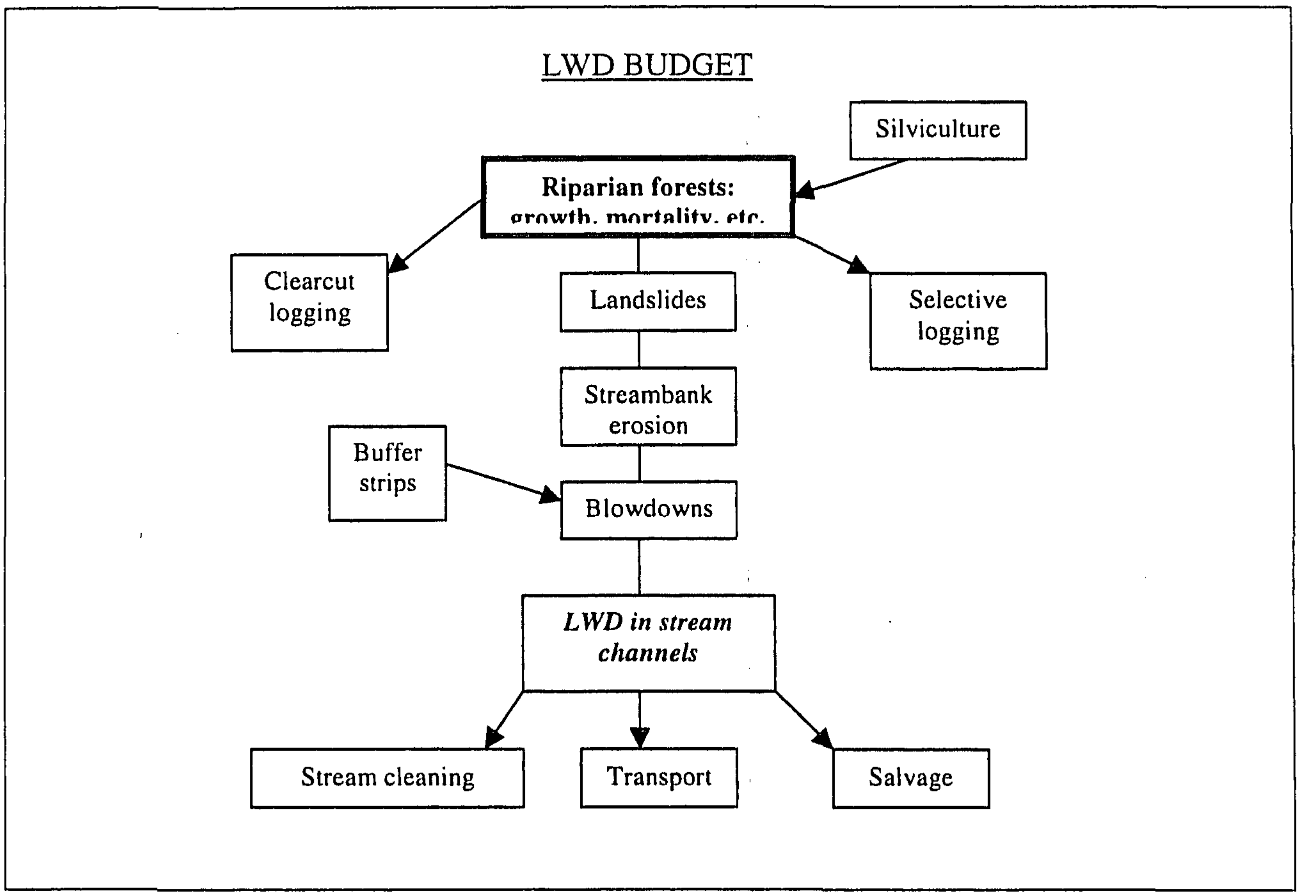

Figure 7. Schematic of LWD budget, as related to timber management practices.

Many other channel parameters (e.g., fine sediment concentration, water temperature) could be substituted for wood in this comparison and the results would be essentially the same. Strong regional differences would indicate that reference values would be appropriate only within the same 'litho-topographic' or 'geo-hydrologic' area. Depending on the parameter, the distribution of values for the population of affected channels would be greater or less than those for pristine channels. However, overlap in these distributions would invalidate the use of single threshold values to regulate management of individual channels. Instead, appropriate target conditions would need to be evaluated by putting the channel in context with its watershed: determining how past and projected production and routing of watershed products interacting within the setting of the watershed, land use, and climatic events have created current trends as monitored by the appropriate parameters linking land use to downstream resources.

Concluding Statement:

Basic point is that channel monitoring is just one of many strategies to gather information to facilitate adaptive management. Need to regard the whole set of links of watershed processes to understand the results of channel monitoring to be pro-active in managing the resources. Sometimes when you examine the whole picture and strategize where you need to collect information you will be led to channel monitoring in some cases, but in many cases not. Must not monitor channels in isolation of other processes occurring across the entire landscape of the watershed.

Clarification Questions:

1. *In Mount Saint Helen's example the conclusion was "wood trumps sediment", is it possible to predict in which settings this is true?* Probably in lower gradient channels where the sediment moving through the system is annually transported bedload. Where (and when) this probably does not hold true is during debris flows, which will often wipe-out the pools from the sheer volume and force of water, wood, and sediment pulsing down the channel. But after the debris flow (which often scours the channel clear of obstructions) new inputs of LWD occur when trees are recruited from bank scour caused by the passing debris flow.

2. *One graph in which you showed old-growth versus second-growth LWD in terms of cubic meters per hectare, you said you could substitute fine sediment for LWD, however wouldn't the relationship (for fine sediment) be opposite of the LWD relationship?* Yes, that is right, that is a good point. I was only referring that any parameter of interest could be substituted for LWD, not that the relationship was the same.

3. *Also, regarding the same graph, you mentioned that LWD is inefficient in creating habitat, wouldn't an even better graph compare the number of pools and pool volume to LWD volume in those two types of channels (old-growth versus second-growth), and to account for that inefficiency and show that it will be hard (or take a long time) to achieve old-growth levels of LWD volume?* Yes, you could probably develop that relationship. I would anticipate lots of variation. There would probably be a positive relationship of pool volume and pool number versus LWD volume, but lots of scatter of the data points.

4. *Regarding Caspar Creek, what was the source of the sediment seen in North Fork Caspar Creek?* Not sure of the source, but the point I was trying to make was that the sediment accumulated there because of the LWD, maybe from upstream (inchannel) sources, but the sediment slowed its passage where the LWD was located, and accumulated. There were no big landslides upstream that obviously contributed sediment to the channel during the study period.

5. *You mentioned there were three factors regarding why channel monitoring wasn't the best tool for adaptive management purposes, the first two were time lags and variability in watersheds, what was the third factor?* The impossibility in deciphering what was going in the watershed by just looking at the channel.

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Time, Space, and Rates of Change in Channel Monitoring

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ABSTRACT

Stream channels can change over several spatial and temporal scales. This talk will focus on how we consider time and spatial scales in relation to understanding channel change. For example, a localized event, such as a tree falling into a stream, may cause an immediate localized response, such as scour of a pool. In contrast, a dispersed disturbance such as a wildfire can lead to a more widespread change (an increase in fine sediment delivered to a stream reach over several months). We can consider channel change to consist of four major parts:

1. a disturbance or perturbation to the system,
2. the time it takes before the system responds (the lag time),
3. the length of time for the change to occur, and
4. the recovery time (or relaxation time) for the channel system to return to its pre-disturbance state (if it does return to a previous state).

A geomorphic change is initiated by some perturbation of the system (an increase or decrease in flow, sediment or wood, for example). The perturbation can be instantaneous (acute) or chronic (persisting over a long time). The channel system may change instantaneously, or there may be a lag time before the system responds. The response time may also vary, from being immediate to taking place over a long time. Finally, the time it takes for a channel to recover also varies, and depends on the nature and size of the perturbation and the characteristics of the particular system. Whether or not a stream returns to its initial state (full recovery) depends on many factors, including whether it is physically possible for a change to be reversed. Spatially, change may be localized to a single habitat unit (scour of a single pool), or can be evident within a stream reach (aggradation), or can be spread across a channel network (increased peak flows due to climatic change or land use).

Important characteristics of channel change to consider are: the type, magnitude and frequency of change, its spatial distribution, the timing, duration and persistence of change, the range of variability and sources of variability. Even monitoring a single process may be approached differently by investigators. For example, geomorphologists may focus on the magnitude of change (depth of scour in a gravel channel), whereas a biologist may be more interested in the timing of change (are there salmon eggs present when scour occurs?). The sequencing of events may also be important (does a channel react differently to a large flood following several drought years as opposed to a large flood following several years of moderate flows?), but few studies have addressed this variable directly. Finally, although we can define statistical significance of channel change, defining the biological significance of a given change is more problematic.

Examples based on 20 years of monitoring data in north coastal rivers will be presented. Results will focus on changes in channel cross sections, thalweg profiles, and particle size distributions in several river types. Time trends evident from this data set will be put in the context of channel indicators proposed by the National Marine Fisheries Service, Environmental Protection Agency, and others.

Introduction

First, the audience was posed a question.– What do you suppose are the similarities between a nation-wide transportation system, the Mount Saint Helens' eruption, a wildfire streaking across the landscape, or a tree falling into a stream? All of these are disturbances to the system, yet they all occur on very different spatial scales, from nation-wide to regional to site-specific. Likewise, what is the similarity between glaciation, slow-moving earthflows, eroding gullies in prairies, and rainfall pedestals caused by rain falling on bare ground? All of these involve the movement of materials across the landscape, yet at very different time scales.

Focusing on channel monitoring, across the landscape we can usually recognize both the severely damaged stream channels and the pristine channels flowing through old-growth forests. However, most of our local channels fall somewhere between these two extremes, not totally destroyed yet not pristine or fully functional. As scientists, we try to sort out the status of these streams and how they have changed (and will change) over time.

Stream channels can change over several spatial and temporal scales. This talk will focus on how we consider time and spatial scales in relation to understanding channel change. These temporal and spatial scales must also be considered when designing and implementing a channel monitoring program.

Some processes such as tree-fall occur in too short a time-frame (and on a very localized spatial scale), whereas other processes (tectonic activity, sea-level change, and climate change)occur on too lengthy of timescales (and over very large areas) to monitor on a practical level. Most. monitoring efforts have focused on events of intermediate scale (grazing, urbanization, timber harvest, or volcanic eruption) that commonly result in disturbances to stream channels.

For channel monitoring, the sampling design may encompass one of four levels of spatial and temporal scales (Table 1). These levels include the following:

1. Regional-scale monitoring includes projects as such the EPA's Environmental Monitoring and Assessment Program (EMAP) and the USGS's National Water Quality Assessment (NAWQA). Because these programs involve sampling over huge areas and for long periods of time funding to monitor processes intensively is usually not available. Commonly, these regional scale projects are not sampled very often.

2. Drainage basin-scale monitoring includes projects such as the monitoring program in the Caspar Creek watershed. These programs involve long periods of monitoring at periodic intervals throughout a single watershed. The advantage of this type of monitoring is the ability to study numerous processes in one basin, such Caspar Creek, where intensive of monitoring (both physical and biological) is occurring both inchannel and upslope. In reality though, in most basins funding is inadequate funding to monitor all processes as intensively as we would like.

3. Reach-scale monitoring is typical of most local monitoring projects, examples include monitoring in Redwood Creek and Simpson's current channel monitoring program. Reach-scale programs involve monitoring a limited set of variables at frequent intervals (at least after every major storm event).

4. Channel unit-scale monitoring involves looking a one habitat unit or physical parameter These are commonly short monitoring programs carried out over a single storm event or a few years to answer at a very specific question, or test a specific hypothesis.

You need to know your question of interest and objectives prior to designing your monitoring program so that you address the problem on the correct scale.

Channel Monitoring Sampling Design					
Scale of Question of Interest	**Length of Monitoring Program**	**Frequency of Monitoring**	**Spacing of Sample Sites**	**Array of Information**	**Examples**
Regional	Long	Low	Large	Broad	EMAP, NAWQA
Drainage Basin	Long	Periodic	Large	Broad	LTER's, Lookout Cr., Caspar Cr.
Reach	Moderate	1 - 5 years	20 channel widths	Focused	Redwood Cr. Simpson streams
Channel Unit	Short	Storm events, continuous	< channel width	Specific	Tom McDonald Cr.

Table 1. Sampling designs for four levels of channel monitoring.

One also needs to consider where in the channel network to monitor. The channel network varies greatly from headwater tributaries to low-gradient, alluvial mainstem reaches. What is the response of interest? Where is the best reach to detect the response(s) of interest related to the specific questions or hypotheses posed? In terms of fish habitat we are more interested in the lower gradient channel reaches than steep bedrock channels..

An ideal situation for monitoring would be a static stream system where there is a specific disturbance, which causes an immediate response by the channel and after some recovery time the system reverts back to its pre-disturbance condition. However, this is not commonly how things work in nature.

The system is naturally dynamic and when the disturbance of interest occurs, there is often not an immediate or noticeable change in the channel condition. There are varying lag times depending on the magnitude or frequency of the disturbance as well as the location of the disturbance. Recovery time is also variable, and often additional disturbances occur before recovery from the initial disturbance(s) is complete. The channel may also never return to its pre-disturbance condition. We need to sort what is happening in the streams and how they respond to disturbances and find out where these processes fall between the Simplistic model and other possible responses in the stream channel.

Investigating Channel Change

During this workshop we want to investigate channel change and discuss how to best monitor this change. The several types and aspects of channel change we should consider measuring (depending on the questions posed) are:

1. Type of change – What kind of change is expected or did occur? For example, does the change involve bedload scour or aggradation, particle size distribution, loading of large wood, riparian condition, water temperature, or flow?

2. Magnitude of change – How big is the change, and is it significant? Or is it within some expected range of natural variation?

3. Frequency of change – How often does the change occur? Is the frequency of a certain event (such as bankfull flow) becoming more or less frequent through time?

4. Timing, duration, and persistence of change – When did the change occur and how long will it persist? For example, during aggradation some surface flow goes sub-surface. How much flow goes sub-surface and for how long will this condition last?

5. Intensity of change (gradual or concentrated) - For example is bank erosion occurring at small intervals annually (20 cm per year), or does massive bank failure occur on one large storm?

6. Spatial distribution of the change – Is the change local or widespread? How is the change distributed across the landscape of interest? For example, deposition of fines in pools may be somewhat predictable, whereas blown-down of riparian trees may be more random and widespread.

7. Variability of change – What is the range of variability in both natural and managed systems? What are the sources of the variability? We have to consider the temporal aspect as well. . For example, the range of variability measured over a five-year period will be much less than the variability over 50 or 100 years. We need to define the time period of interest as well as the spatial scale of interest.

8. Sequencing of change – What is the relationship of the recently measured change to the past history of changes in the stream channel of interest? We must look at the legacy of change that has already occurred to better interpret the changes we are currently observing.

Also the occurrence of a certain event may have different significance depending on one's field of expertise. For example, the geomorphologist may be more interested in the depth of scour as related to the size of the storm event (magnitude), whereas the fisheries biologist may be more concerned with when the scour occurred (timing) (during egg incubation?).

Case Example: Redwood Creek

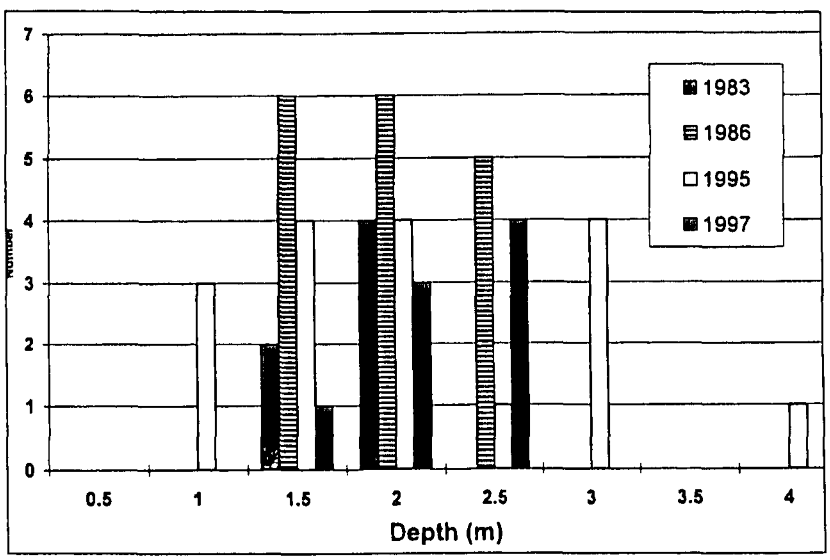
The remainder of the discussion will focus on 20 years of intensive monitoring in Redwood Creek . The monitoring program includes a network of cross-sections, longitudinal profiles, and particle size counts in Redwood Creek, Little Lost Man Creek (a small pristine tributary to Prairie Creek) and Bridge Creek (a larger anadromous tributary subjected to past logging, but that is recovering).

Thalweg Profiles over Time

The assumption used in this analysis of thalweg profiles is that the more variable the thalweg profile (greater range of pool depths), the better the stream habitat is for fish. The variation in depth is indicative of a diversity and complexity of habitats.

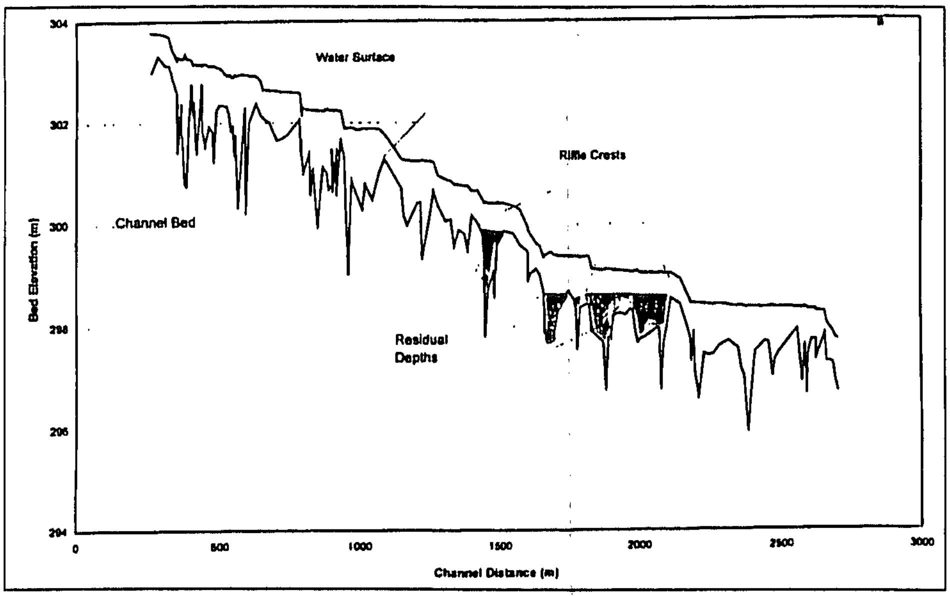
Figure 1 shows changes from the initial 1975 thalweg profile, where the channel had filled with sediment after large floods in 1972 and 1975 . The flood resulted in many landslides. The streambed was flat and almost featureless, and was referred to as a "pool table" by field crews working at that time. By 1986 the channel had cutdown and pool development was evident.

Figure 1: Pool Depths, 1983 to 1997



Pool frequency and depth increased between 1983 and 1986 (the number of pools increased from six to 11 in a 2.5 km reach). Pool frequency in 1995 was similar to that in 1986, but pool depths continued to increase. However, after the 1997 storm event (a 12 year return interval) the channel aggraded again, causing a drop in pool frequency and decrease in pool depths.

Figure 2: Longitudinal Profile in more detail

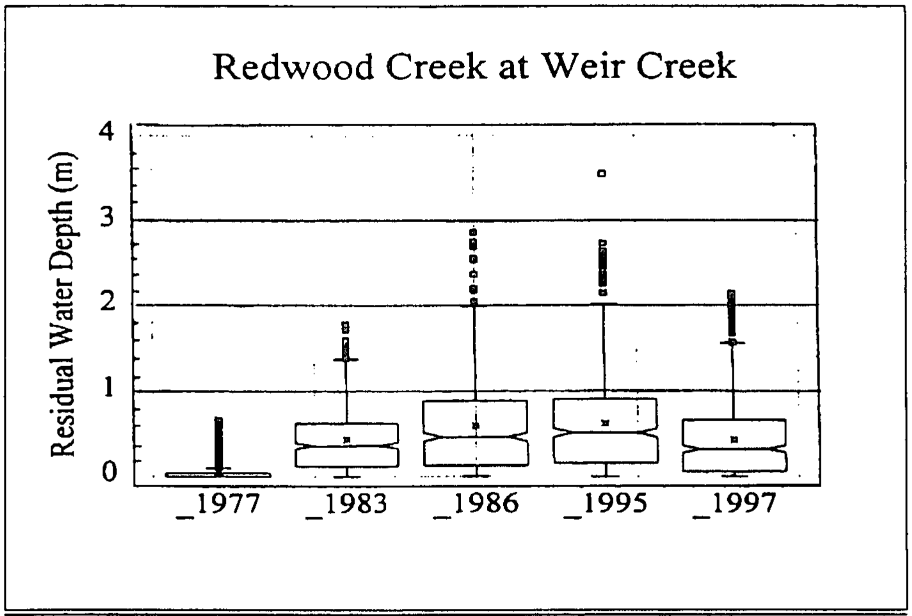


The plot above is a thalweg profile of the study reach Redwood Creek at Weir Creek in 1997. The identification of pools or other habitat units is somewhat subjective. Different surveyors define pool boundaries differently. For this reason, we considered just the residual water depths (a discharge-independent measurement based on the downstream riffle crest) and plotted the distribution of these residual depths. The resulting plot is a series of varying depths over the measured length of channel surveyed. This distribution of water depths can then be analyzed for trends over time.

Figure 3: Box Plots of the Range of Residual Water Depths

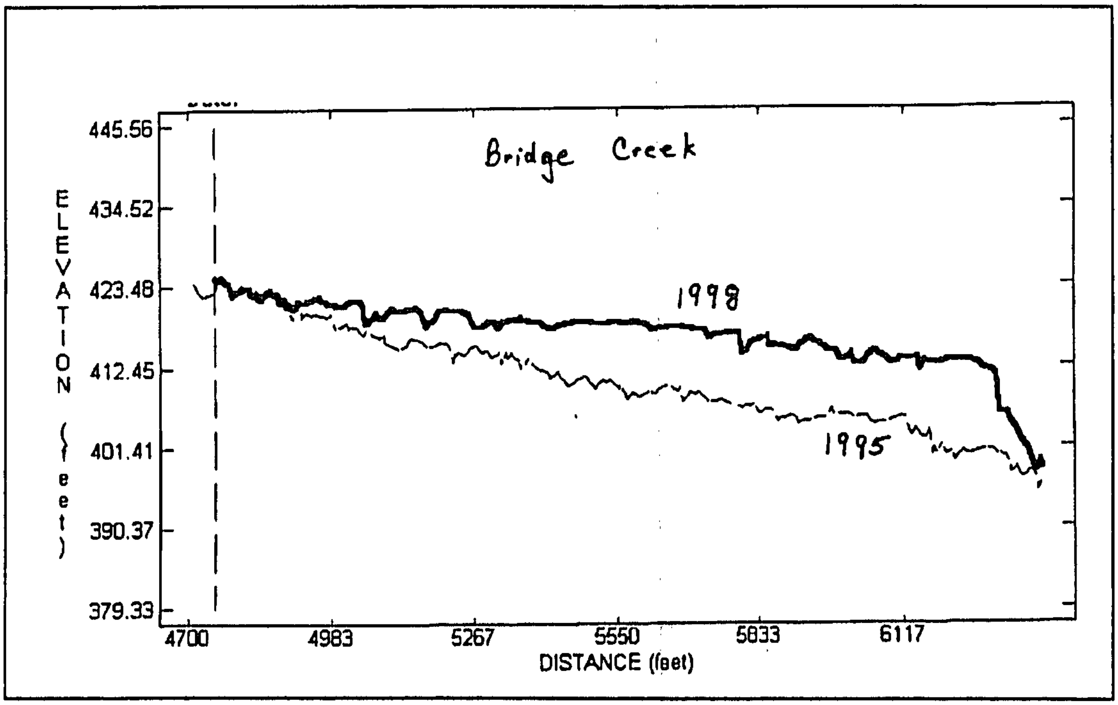
Figure 3 shows the range of variation in residual water depths in Redwood Creek from 1977 to 1997. The box boundaries enclose 25 to 75% of the data, the '*' is the mean of the distribution and the notch is the median. The distributions of residual water depths was significantly different in all surveys from 1977 to 1995. Following the 1997 storm the distribution of residual depths returned to 1983 conditions. The previous graph of pool number and depth showed no statistical significant difference, mainly because of the small sample size (only 10 pools). Considering the entire distribution of residual water depths allows for a closer look at the change in channel conditions.

Figure 3: Box Plots of the Range of Residual Water Depths



Thalweg profiles were also measured in Bridge Creek where a large log jam was a major feature in the channel for most of the study period. The debris jam was partially washed out during the 1997 storm event, and since then the stream morphology has changed tremendously. In 1995, frequent pools existed, spaced about 1.5 to 2.0 channel widths apart. In the same stream farther downstream, in a more confined channel reach, there are fewer pools, spaced about 4.0 to 6.0 channel widths apart and pool spacing is more variable.

Figure 4: Thalweg Profile of Bridge Creek upstream of newly formed debris jam



Effect of Debris Jam Formation in Bridge Creek (1995 versus 1998)

The debris jam that washed-out during the 1997 storm (about a 12-year recurrence interval in the Bridge Creek sub-basin) reformed in the channel farther downstream (Figure 4). The channel near the new jam originally had a variable (bumpy) thalweg profile (1995) but when the debris jam repositioned itself, the same reach of channel became smoother and lost its variable thalweg profile (1998). Aggradation of sediment above the new debris jam caused the filling of pools in this particular stream reach.

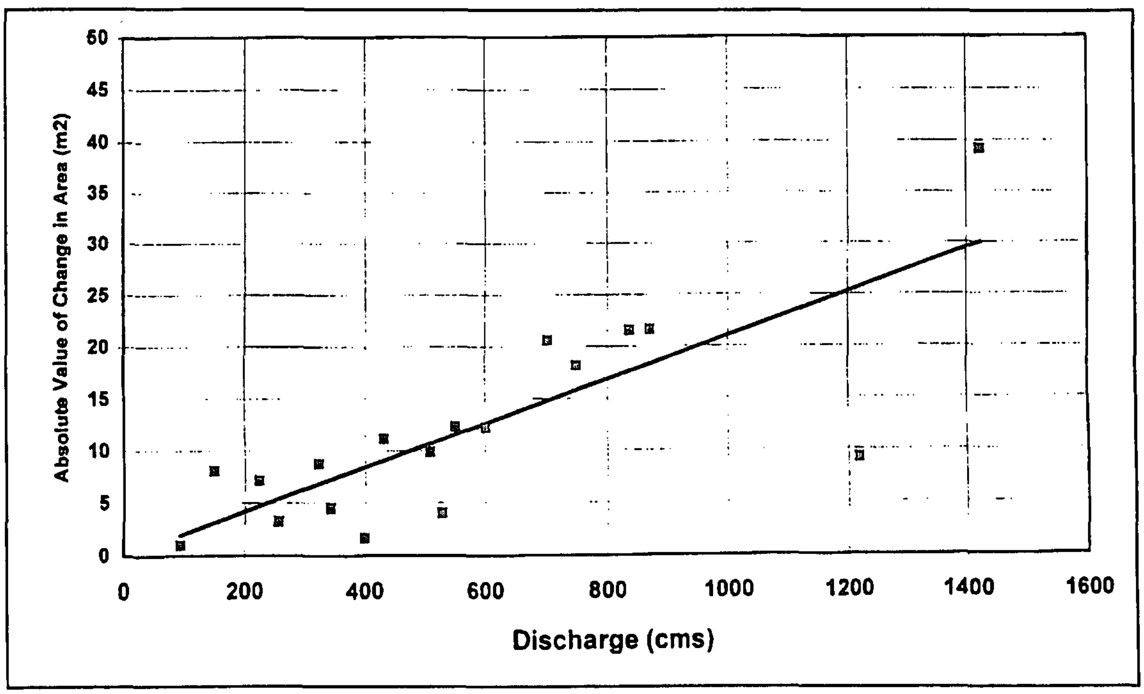
Channel Cross Section Surveys

Along the 100 km length of Redwood Creek about 60 cross sections are monitored annually or after major floods. What have we learned from 20 years of cross section monitoring? The general trend is that upstream where the channel is narrower, less change has occurred relative to the wider cross sections in the lower channel. Some cross sections do not follow this relationship of increased change with increased drainage area, however, and these cross sections were located in unconfined channel reaches (discussed later).

Most cross sections exhibited aggradation following floods in 1972 and 1975, resulting in changes in channel shape and width aggraded in 1975. Immediately following aggradation, sediment levels declined exponentially for five years. Nevertheless, as the monitoring continued, the exponential decay model broke down, and other patterns of change emerged, with periods of both scour and fill in different parts of the channel. One needs to examine other processes occurring in the watershed to explain the long-term patterns of channel change.

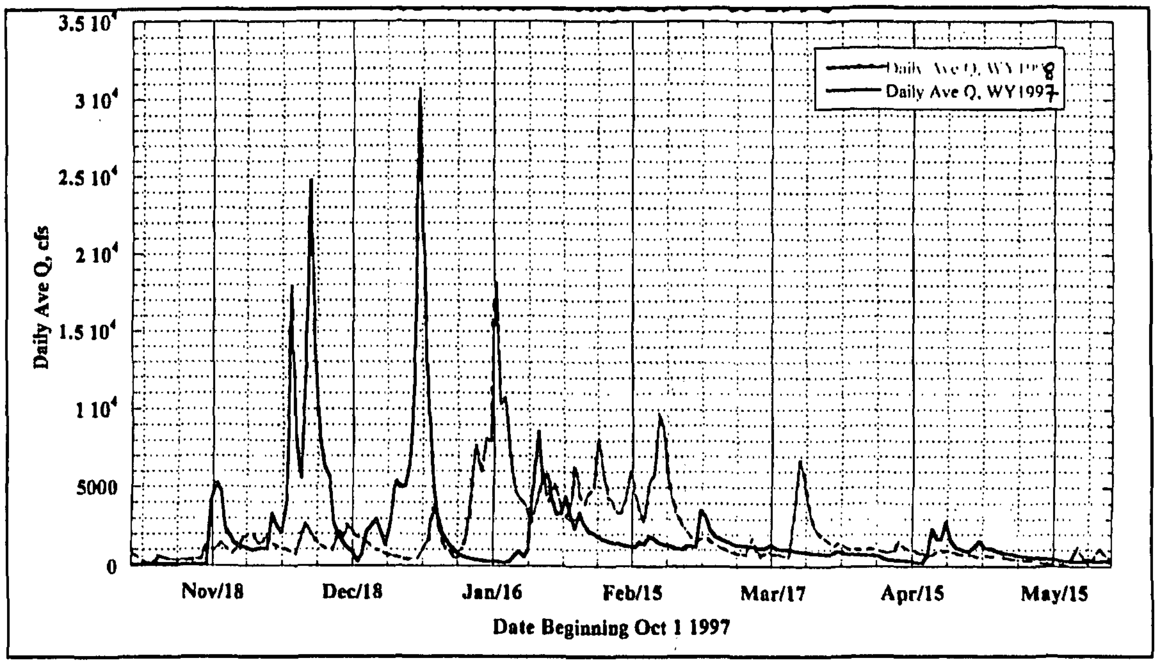
Channel changes can be interpreted as a function of the size of flow and the duration of flow. Figure 5 shows the amount of channel change (scour or fill) measured at a cross section in Redwood Creek. In this gravel bed river, higher peak flows produced greater channel change. This trend does not necessarily hold in all rivers. Channels with coarse bed material may show little or no change until a critical flow is reached (a threshold response), at which point bed material can be moved and channel shape can change. Consequently, the interaction of bed particle size with the geomorphic and hydrologic characteristics of the river will influence when and where channels respond to watershed changes.

Figure 5: Magnitude of Channel Change vs. Peak Flow at a Single Cross Section



In Redwood Creek the size of the peak flow seems to influence channel change more than the duration of high flows. In water-year 1997, the peak flow was the highest flow recorded since 1975, and had a recurrence interval of about 12 years. This flow occurred as a single peak event. The following year (water-year 1998) the peak flow was not as high, but there was a longer sustained flow of a magnitude to move bedload (discharge greater than 1,000 cfs). More scour and fill resulted from the 1997 peak flow, than occurred during the long-duration flows in 1998.

Figure 6: Daily Average Flow and Channel Change (1997 versus 1998)



Channel confinement also affects how the channel cross section responds to discharge. In this study, an unconfined cross section is defined as having a valley width greater that three channel widths. In unconfined channels there is a higher rate of change in cross sections with increasing discharge. Twenty years of channel monitoring is just beginning to show the range of natural variability in different types of channels within the Redwood Creek watershed. To more fully understand channel change, a long-term commitment to monitoring is needed.

Mean Change in Overall Bed Elevation

In a given year, how much is the channel bed going up or down? Over 20 years, Redwood National Park and the USGS conducted 520 cross section surveys. During most years and at most stations, the bed elevation barely changed. But in certain areas, during high flow events lots of change can occur. The same trend is seen in channel area - most of the time there is very little change, but during high flow events large changes can occur.

Relationship Between Change in Thalweg Elevation versus Elevation Change of Entire Cross Section

Can we measure just the change in the thalweg of a cross section and predict what the change is for the entire cross section? What is the relationship between changes in the thalweg and entire cross section? A plot of annual thalweg elevation change against annual bed elevation change did not show a good relation between the two. Thalweg change can be a very localized event (scour around bedrock or LWD), whereas change in mean bed elevation accounts for the entire cross section, including what is occurring on the gravel bars as well as the thalweg. One must examine several components of channel change (longitudinal and cross-sectional) It is important to have an integrated view of the stream system which includes changes in wood loading as well as morphologic changes.

Bridge Creek: Magnitude of Change in Cross Sectional Area

We observe similar relationships among channel change, channel confinement and flow magnitude in Bridge Creek, a tributary to Redwood Creek. Unconfined cross sections along Upper Bridge Creek showed greater change than confined cross sections in lower Bridge Creek Suggestions have been made to examine the width:depth ratio of a cross section and use this as an indicator of stream health. From the literature, the ideal width:depth ratio is about 10:1. Most cross sections measured in Redwood and Bridge Creek fall out of the 10:1 ratio, some exceed 20:1 or higher (40:1). Redwood Creek has certainly been affected by human activity, but 1936 air photos already show a wide channel with many gravel bars. We need to examine the variation of streams regionally. Some rivers in northern, coastal California may never have had a 10:1 width:depth ratio.

Clarification Questions:

1. *You pioneered the concept of regional indexes of channel geometry, and others (such as Rosgen) have made great career advances by trying to formulate these regional indices, do you feel that they have merit or utility in regards width to depth ratio?* One has to consider the particular constraints put on any given watershed. What is the underlying geology? For example, is an earthflow impinging on a channel and confining the river, or is introducing large blocks of material that will cause the width/depth ratio to change. One can make some broad generalizations about regional characteristics, but to interpret changes in a given stream reach, the specifics of the watershed need to be evaluated.

2. *Wouldn't the general response after some aggradation event be a downcutting as that material moves past the cross section?* Yes, if the subsequent flows are high enough to transport the caliber of that material. We are also interested in the pattern or shape of the cross section as scour occurs. Is it scour evenly distributed across the channel, or are certain spots downcutting or incising more? Also, we need to evaluate the potential for further aggradation from sediment sources farther upstream because there are lag times with some sediment transfer processes.

3. *Is it possible as we see gravel bars building and start confining higher and higher flows, is it then possible to see an incision and confining of the thalweg as well?* There may be two different processes happening: a) the elevation of the bars may be increasing without changing the thalweg elevation or b) as the bars are building up, the flow becomes concentrated in a smaller cross-sectional area, resulting in incision of the channel bed and lowering of the thalweg. Because most change occurs at high flow, how much flow is actually confined between the gravel bars during high flow events will influence subsequent downcutting.

4. *What is the utility of using these types of long-term channel monitoring parameters as collected on Redwood Creek for assessing stream health and, as well as, identifying and quantifying impacts of upslope practices?* That is a key question. Over the years I have been accused as being maniacal by spending so much time analyzing cross section and longitudinal profiles. Over the years we have tried to find out if we can use this information to assess stream health and link changes to upslope causes. The monitoring we have conducted is useful for trend information but cannot be used to assign direct responsibility to a certain landowner (say ten miles upriver) whose activities in the basin may affect stream health. As Tom Lisle discussed, we have the ability to detect channel change, but not necessarily to link change to specific hillslope activities. What we need are upslope monitoring tools to look at those activities, to detect changes in the inputs of watershed products (sediment, wood, heat and nutrients) and to better understand the routing of sediment from upslope to fish-bearing channels. At this point we cannot look back miles upslope to a specific road, landing, or clear-cut and link it to a pool that filled miles downstream.

5. *In some regions the sediment in storm flows will transport through the cross section and you do not detect change (of sediment passing through), so your cross section has failed to assess that aspect of stream health.* This gets back to the question of interest and monitoring objectives. You wouldn't focus on cross sections as much if your objective was to quantify movement and transport rates of bedload or suspended sediment. Instead, you would need to establish a gaging station with sediment transport measurement capabilities. Alternatively, if you have selected the filling of pool as a measurement of stream health, you wouldn't want to be sampling pools in transport reaches. I'm sure we'll hear more about defining specific objectives for monitoring later in this conference.

6. *There have been studies looking at sediment routing in mainstem Redwood Creek. What is the usefulness of a basin-wide sediment budget to get towards identifying sources and causes of sediment entering the system?* Sediment budgets are useful tools to quantify how much sediment comes from landslides, road failures, gullies, etc. in Redwood Creek. We can say "X" amount of sediment entered the channel and this was the change we measured in the channel. One of the difficulties is pinpointing an exact cause of an event from what is often an air photo exercise. For example, was road construction responsible for the landslide, was the road just associated with the slide, or was it an inner gorge failure that would have occurred anyway, or did aggradation of the channel cause cutting at the toe of a hillslope feature which destabilized the hillslope? As large numbers of landslides, gullies, culvert failures, etc. are analyzed , associations among causal mechanisms will become clearer.

Management Objectives for Long-term Channel Monitoring on Industrial Forestlands

Lowell Diller, Simpson Timber Company, Korbel, CA

ABSTRACT

Simpson Timber Company has been in the process of implementing an aquatic monitoring program since 1993 as part of the development of an aquatic Habitat Conservation Plan. The problems that we have encountered with an approach to monitor changes in stream channel characteristics that result from hillslope activities has led to a refinement of realistic management objectives for this monitoring approach. The fundamental objectives have been reduced to: 1) document changes in stream morphology in selected aggradational reaches of 3rd-4th order sub-basins (3000-6000 acres); 2) collect data that will provide a better understanding of channel processes and stream dynamics in streams of this size and 3) use long-term trends in key channel variables to assess changes in sediment delivery due to hillslope processes. The trials and tribulations associated with implementing this monitoring technique also brought a focus to the need to address certain critical attributes of any monitoring approach.

We believe that the successful implementation of this monitoring approach requires the following critical attributes:

1. variables being measured represent processes being monitored;
2. monitoring focused on processes rather than "average conditions" or "desired future conditions";
3. minimum time lag between an action and a change in the variable being measured is essential;
4. field techniques involve a minimum of subjectivity and key variables are truly quantitative (repeatable over time and among field crews) and
5. data amenable to development of statistical hypotheses (use of rigorous statistical tests to detect change).

As is the case with any monitoring approach, there are some practical constraints associated with this long-term channel monitoring approach. Because it is relatively labor intensive and therefore costly, it is not possible to establish large numbers of the monitoring reaches across the landscape. Coupling this with the subjective manner in which the monitoring reaches are selected, there are concerns about the inferences that can be drawn to other sub-basins throughout the region. There is also concern about acceptance from the scientific community and regulatory agencies since the technique has not been widely used in this context. Finally, it should be noted that the implementation of this monitoring approach is not completed. There are several critical missing elements, which include the development of threshold levels that would trigger an assessment of hillslope activities. If an assessment of hillslope activities is warranted, the critical feedback mechanism to management activities has not been established along with approaches to distinguish between natural and anthropogenic changes.

This presentation will focus only at the objectives of the draft monitoring protocol being proposed by the FFFC, which is the focus of this two-day workshop. I am not attempting to address watershed monitoring in general. Although my background is not in channel processes or fisheries, I have been involved with the development and initial implementation of this draft protocol on Simpson's property. This experience has given me a perspective on the difficulties of both developing the objectives and questions, as well as, the actual implementation. I'm like many other land managers, in a sense trying to make resource-based decisions, often with very limited or incomplete information. I am able to offer the perspective of how Simpson became involved with monitoring channel conditions and how we arrived at using the protocol being discussed today.

<u>Critical Attributes of Simpson's Channel Monitoring Program</u>

1. *Variables being measured represent processes being monitored.* One of the problems Simpson ran into prior to using the FFFC protocol was using methods not suited for channels in coastal, northern California. The methods were flow dependent and detected wide changes in channel attributes. However, these changes were attributed to differences in base summer flow when the channels were monitored and not physical changes in the channel.

2. *Monitoring focused on processes rather than "average conditions" or "desired future conditions".* The natural processes all have a wide range of variability and monitoring should be focused on capturing changes in processes. The concept of a "desired future condition" is a bit arrogant, because we assume to know what the channel should look like when we have little or no information to support this opinion. Differences between watersheds is often attributed to geology which strongly influences conditions present in any given channel.

   Simpson is also monitoring conditions in Class II (non-fish bearing) streams with regards to the presence or absence of torrent salamanders and tailed frogs. This work provides an example of the impact of geology on biological systems. These amphibian species are very sensitive to elevated water temperatures (more than salmonids), and are negatively impacted by fine sediment inputs that result in embedded stream substrates. Our studies indicate that geology dictates the presence or absence of these species more than land management does. We detected a pattern of distribution from north to south across our property attributed to geology (consolidated parent material in the north versus mostly unconsolidated in the south). Regardless of the management history, a high proportion of streams in the north (Smith River to the lower Mad River) supported these amphibians while few streams to the south (Humboldt Bay tributaries and lower Eel River) supported these amphibians.

3. *Minimum time lag between an action and a change in the variable being measured.* This a fundamental problem associated with this monitoring protocol and we are trying to deal with it. In the developmental state of implementing the protocol, Bill Trush pointed out that the monitoring reach should occur in the upper portion of the first depositional reach of the channel network to minimize the lag time between hillslope events and the response in the channel. We plotted the longitudinal profile from topographic maps to identify the transport, transitional, and depositional reaches of the selected streams. Field verification was conducted prior to finalizing site selection and implementing the protocol. Because of the unavoidable time lag associated with this technique, its use should be limited to smaller streams and would not be appropriate for large streams such as mainstem Redwood Creek or the Mad River.

   Why not measure suspended sediment if you want to reduce lag time? Several reasons (my own reasons): a) there is high variability in suspended sediments from system to system, such as managed tributaries in the lower Mad River that have less suspended sediment than streams from areas of the upper basin where very little logging has occurred; b) because you're monitoring the obvious – why monitor something that you know is occurring and can be attributed to any land management activities; and c) are there any ways to tie the physical measurements of suspended sediment to the biological impacts? In the context of management of industrial lands, there do not seem to be any benefits associated with monitoring suspended sediments.

4. *Field techniques involve a minimum of subjectivity and key variables are truly quantitative (repeatable over time and among field crews).* This is extremely important because timber harvesting is heavily regulated and monitoring must be objectively measured so that results are statistically valid. Methods must be repeatable between crews in the field, because over the life of a long-term program, change in crew members is inevitable.

   As a zoologist my best example regarding subjectively and the difficulty of repeatable measurements is the difficulty of measuring live snakes, especially poisonous species such as rattlesnakes. In the past, my wife assisted me in field studies of rattlesnake, and we would often struggle to straighten the snake out for a measurement. I would say "It isn't straight", and eventually as frustrations mounted she would comment, "O.K. Lowell how long do you want this snake to be?" This example can be related to some channel monitoring techniques, for instance V*. This was tried as a variable in Simpson's program, but was soon dropped when we measured variation in V* due to amount of force used to drive the V* rod into the substrate settled in the pools.

5. *Data amenable to development of statistical hypotheses (use of rigorous statistical tests to detect change).* Again, in the arena of timber harvesting and other resource-based extraction activities, statistical rigor is an important requirement regarding any management decisions. This was the primary reason in hiring Trent McDonald from West Inc. to provide statistical rigor to the results of channel monitoring.

<u>Fundamental objectives of Simpson's Long-term Channel Monitoring Program</u>

1. *Document changes in stream morphology in selected aggradational reaches of 3rd-4th order sub-basins (3000-6000 acres).* The monitoring program is focused to these specific areas of the channel in these mid-sized tributaries. The protocol was not designed for monitoring larger, mainstem channel reaches.

2. *Collect data that will provide a better understanding of channel processes and stream dynamics in streams of this size.* Over the course of a long-term monitoring program, Simpson will eventually gain a better understanding of channel changes and how they are related to watershed processes and the natural variability inherent in streams on their property.

3. *Use long-term trends in key channel variables to assess changes in sediment delivery due to hillslope processes.* Our "bottom line"objective is to be able to document a statistically significant changes in selected critical attributes of the channel that respond in predictable ways to changes in sediment supply.. This may seeem a bit too focused and missing other

aspects or processes occurring in the watershed, but the alternative risk associated with expanding the objectives is that no definitive conclusions can ever be reached.

Practical Constraints of Long-term Channel Monitoring Program

1. *Cost.* This type of program is expensive, thus there are limitations to how many reaches are selected for long-term monitoring. However, to provide useful information the monitored sites need to spread sites across the landscape to capture differences in geology and hydrologic characteristics.

2. *Limited ability to make inferences.* The limited number of sites selected for long-term monitoring also limits the ability to make inferences widely across one's ownership.

3. *Endorsement of the scientific community and regulatory agencies.* This leads to the main purpose of holding this workshop, to discuss the protocol, its usefulness as an adaptive management tool, and methods to strengthen the protocol. Eventually, acceptance by both the research and regulatory scientists is necessary.

Additional Elements to be Developed during Implementation

These additional elements for development are crucial because this protocol is in a draft stage and both Simpson and the FFFC are interested in further refinement of the methods to improve its utility as a management tool.

1. *Threshold levels that trigger an assessment of hillslope activities.* We have yet to determine what the thresholds of channel parameters would be to trigger a look upslope that would lead to changes in management activities. Just because a statistically-detected change has occurred doesn't mean that there is a biological response or impact.

2. *Feedback loop to management activities.* This was discussed in the first two presentations and is also related to my third point. That is, once we detect channel change, how do we tie this response back to management activities?

3. *Methodology to distinguish between natural and anthropogenic changes.* How do we separate the natural processes from the human-related alterations of the landscape? In my opinion if all the indicators are going positive (things are getting better) there's no need to look upslope. But when channel change reverses, and conditions degrade, then the question is when and where do we look upslope to assess the effects of management? And what do we change to prevent the impacts from re-occurring?

Attainable Objectives for Long Term Channel Monitoring Programs

Randy D. Klein, Redwood National and State Parks, Arcata, California

ABSTRACT

The primary goal of stream channel monitoring programs is typically well conceived, i.e., to document conditions and trends of stream channel physical characteristics reflecting aquatic habitat quality and quantity. However, the most common objective, to provide timely feedback for adaptive management, may not always be attainable. Because of time delays, downstream attenuation of impacts, and downstream aggregation of responses from all upstream sources, channel monitoring is of limited value in providing information for adaptive management in a timely manner. Nonetheless, regulatory agency staff, private land managers, advocacy groups, and individual citizens commonly expect an unrealistically direct and immediate linkage between channel responses and management disturbances.

For defining realistic, attainable objectives, it is useful to distinguish between research and monitoring. These are all too often confused, leading to inappropriate objectives and unrealistic expectations. I distinguish research as very focused monitoring which is designed to test hypotheses relating to land use effects, whereas simple monitoring would be more broadly focused on ambient conditions and trends over larger areas and longer time spans. For example, a research objective might be to examine the effects of yarding methods on hillslope erosion and resultant stream sedimentation. A paired basin study could be designed to contrast several areas with different yarding methods (tractor, high lead, skyline) with a similar area left undisturbed. To be successful, independent controlling variables (geology, slope, climate) would have to be similar for all areas, allowing differences to be reasonably attributed to yarding methods. A larger research effort could be to examine how yarding methods might increase erosion on areas with different slopes or geology. However, as the number of specific research objectives increases, the necessary sample size increases as well. This results in greater costs and more difficulty in finding appropriate study areas and ultimately, it may be difficult to use the results to make quantitative statements about responses in areas with different lithologies or climatic regimes.

Another difficulty faced in short-term research projects is the weather. It is common for such projects to be subject to climatic extremes: a dry spell during which erosivity is unusually low, or a wet spell during which erosivity is unusually high. Only with long term commitments can we be reasonably sure that a range of weather conditions and resultant channel/hillslope responses can be characterized. This sort of commitment is most feasible within the context of long-term ambient monitoring programs.

Some examples from northwestern California serve to illustrate both successful and unsuccessful monitoring approaches. Prairie Creek, tributary to Redwood Creek, has been intensively monitored since 1990 to quantify channel responses to elevated erosion from highway construction. Results of streambed textural monitoring (riffle gravel samples and artificial redds) gave results that were difficult to relate specifically to the disturbance, probably because of local variations in channel slope, width and roughness. However, other, unexpected insights were gained into influences of tributary "point sources" on main channel sediment size and the effects of annual runoff variability on recovery processes and time. Results also served to highlight shortcomings in setting numeric "target" conditions drawn from the scientific literature to evaluate channel recovery and effectiveness of best management practices.

Monitoring of suspended sediment yield, however, resulted in a better "payoff" in terms of meeting study objectives in this case. Comparing suspended sediment yields on a main channel above and below an impacted tributary provided a reasonably solid basis for quantifying the magnitude of disturbance effects and determining when recovery was achieved. The relatively short-term responses in suspended sediment production (and turbidity) from disturbances make this one of the few channel responses suitable for timely feedback for adaptive management.

Other examples illustrate how our process/response expectations can be misleading. We typically expect channel bed sediments to get finer with increasing management intensity. However, some studies show the opposite effect,

depending on the specific nature of the management practices. For example, one study showed coarsening of the streambed with increasing management disturbance, but the dominant disturbance was removal of large woody debris (LWD). One might envision a case where intensive logging and road building elevated fine sediment levels in the channel, but concurrent LWD removal more than offset the tendency for bed fining, leading to the rather bizarre conclusion that stream condition improves with increasing disturbance.

Over the long term, channel monitoring can successfully inform managers how to improve management in a very broad sense, but this approach is reactive, not preventative: it requires damage to aquatic ecosystems to be realized prior to refining management practices. Alternatively, monitoring of source areas ("hillslope monitoring") is of greater value in the near term because it is capable of providing more immediate, site-specific and practice-specific feedback and, more importantly, can be effectively used for preventing failures which could cause channel impacts downstream. Moreover, hillslope and channel monitoring together can provide the best means of isolating management effects from natural processes and rates in time and space, thus providing a reliable basis for adaptive management.

Introduction

How many people have seen "Monty Python and the Holy Grail"? The inspiration and idea behind this conference really ties into theme of the movie. What's the one thing we can measure in the channel, instantly relate back to specific land management practices, tweak these and improve stream habitat. As we have already seen this is a very difficult association to make. I feel most of the presenters at this conference are more like the knights who say "Ni!"

There is a distinction between research and monitoring (Figure 1). Research is intended to look at causes and effects and link those directly and monitoring which is supposed to look at ambient trends and conditions in watersheds. Some monitoring, if done right, and is adequately funded for a long period of time, down the line may be able to assist us in assigning cause and effect as research is intended to do. I'm mostly a monitoring person, but I dabble (or like to think I do) in research related projects. In the past I've conducted monitoring in hopes of relating it to cause and effect, only to find out it couldn't. During this presentations I plan to share some of my failures, and hopefully a few of my successes.

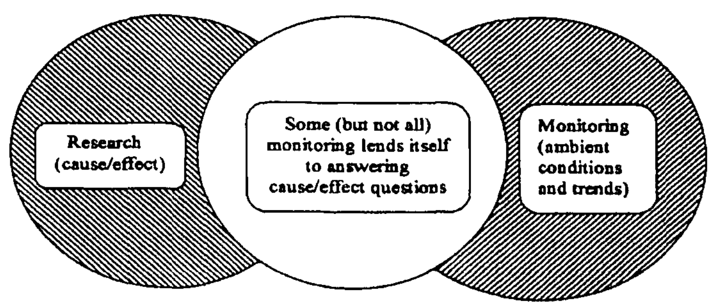


Figure 1. Overlap schematic of research and monitoring.

This schematic is similar to the overhead presented by Tom Lisle, showing the pathways and possible relationships between cause and effect (Figure 2). The schematic fits into my talk, by the fact of what you define as a cause and effect, or what you perceive to be the linkages of processes dictates how you formulate realistic objectives. This understanding is vital in setting objectives that can be successfully answered.

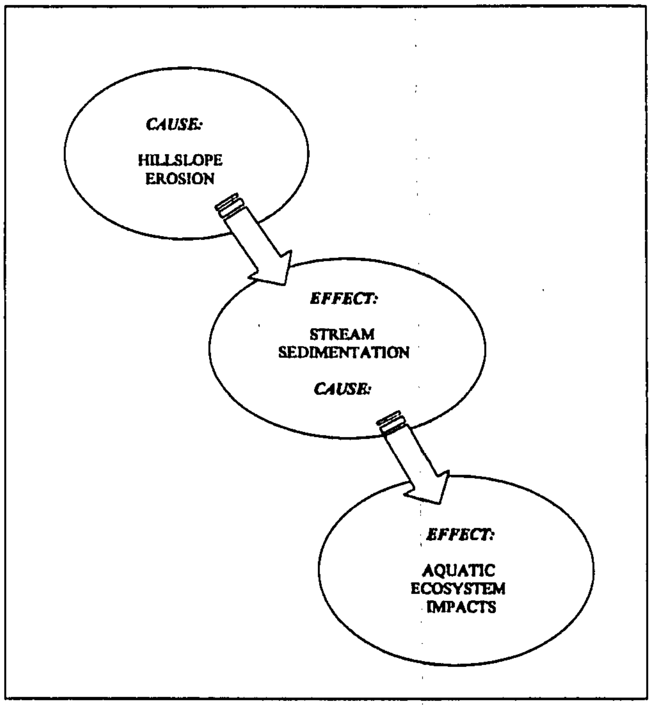


Figure 2. Simplified schematic of the cause and effect relationship of hillslope processes and channel response.

Adding the aspect of aquatic ecosystem impacts is the most difficult link to make back management practices (Figure 3). Probably because in the series of cascading events and inter-related processes, aquatic ecosystem impacts are the final step. The more attention we pay to this final link (as related to hillslope activities) the higher likelihood we can eventually establish a cause and effect relationship.

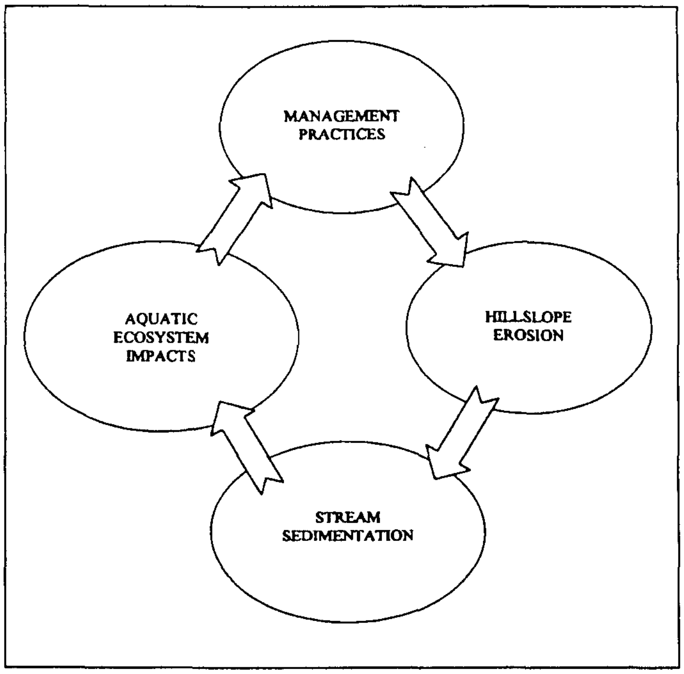


Figure 3. More elaborate schematic of the cause and effect relationship between hillslope practices and channel response (includes biological responses).

Road Related Debris Slides

Five criteria related to landslide characteristics to assess risk of future failures:

1. Most common on slopes > 30%
2. Most common on the shist portions
3. Inner gorge areas
4. Wet soils
5. Headwater swales

Bridge Creek Thalweg and Cross Sections (before and after jam removal)

On Bridge Creek a thalweg profile and cross sections were measured above the debris jam prior to removing the jam because of fish passage concerns. We wanted to quantify changes in channel conditions (sediment response) after the debris jam was modified. The channel reach below the jam was a transport reach, even though lots of sediment was released from behind the jam not much of a response was detected in the downstream thalweg profile and cross sections. Knowing the characteristics of the channel upfront aided in having an idea of what type of channel response might occur.

Prairie Creek (post-Highway 101 bypass)

Prairie Creek is a Redwood Creek tributary located several miles north of Orick, California. It is a fairly small watershed (about 40 square miles) that has been subjected to relatively little land management, especially in the upper portion. In late October of 1989, a moderate storm hit the watershed and caused tremendous inputs of sediment off the Highway 101 bypass construction site. The tributaries on the east side of the basin were most affected, especially Brown's and Boye's Creeks.

We studied the effects and movement of the sediment through Prairie Creek for nine years. The first part of the study was during the tail of the drought and the final four years occurred during relatively wet years. Looked at two streams very closely for those nine years, monitoring both discharge and suspended sediment. The control reach was Prairie Creek above Brown's Creek (about 4.0 square miles) and the first treatment reach was Prairie Creek downstream of Brown's Creek.

Flux of Suspended Sediment in Prairie Creek (above and below Brown's Creek)

The response immediately after the bypass incident was a large flux of suspended sediment in the lower reach (Figure 3). However, the next few years were drought conditions, with relatively low peak flows and the suspended sediment values were nearly the same. Then four wet years occurred and the differences between the control and treatment reaches became apparent again. The interpretation is that during the first year moderate flow events flushed the fines from the surface of the channel bed, then during the following years suspended sediment levels were low, until larger storms eventually mobilized the coarser bed material and released fines that were stored sub-surface since 1989.

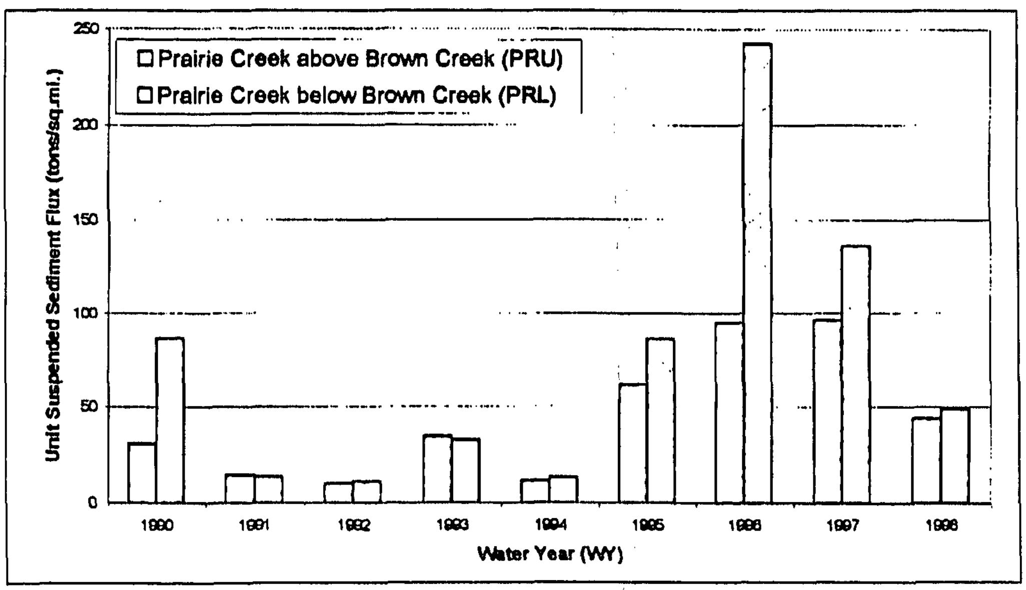


Figure 3. Unit suspended sediment flux for Prairie Creek above and below Brown Creek: WY 1990-1998.

Main point: you can never tell what the weather (or flow patterns) are going to be over the length of a monitoring program. During short-term studies to examine processes driven by weather you might only document one extreme or the other (wet years or drought years). Really need funding to carry these types of studies over a number of years to capture variations in cyclic winter weather patterns.

Timing of Suspended Sediment Flux versus Timing of Salmonid Spawning

We examined the flux of suspended sediment as related to storm runoff superimposed on the approximate run timing of the three salmonid species. Because chinook salmon generally spawn first, they eggs and young are subjected to the effects of most of the winter's storms, then coho, and finally steelhead. The progeny of earlier spawning fish are thus subjected to more intrusion of suspended sediment. During the January 1997 storm (highest peak discharge of the nine year study), the chinook and coho were the hardest hit and the steelhead came in the latest, dug their redds and very little happened hydrologically after that.

The Highway 101 bypass failure was a discrete event, unlike most landuse disturbances that often occur on a repeated basis. This made the link back to the impact from monitoring the physical change and the biological response much easier. Utilized artificial redds with live steelhead and coho salmon eggs to assess the effects of suspended sediment. Also measured permeability within the artificial redds. One main problem was the consumption of salmonid eggs by sub-surface olgacete worms (confounded the study results). After the incubation period the artificial redds were pulled and then looked at influx of fines into the initially clean substrate.

Unexpected enlightments of the study was the graph of suspended sediment input along the longitudinal profile of Prairie Creek (Figure 6). Before marking the locations of the impacted tributaries, the suspended sediment values appeared variable, rising and falling (with an overall increase in the downstream direction). The impacted tributaries introduced sediment much like a point source into Prairie Creek. Just below each tributary there was a spike of suspended sediment that would eventually taper off until the next impacted tributary, then another spike occurred.

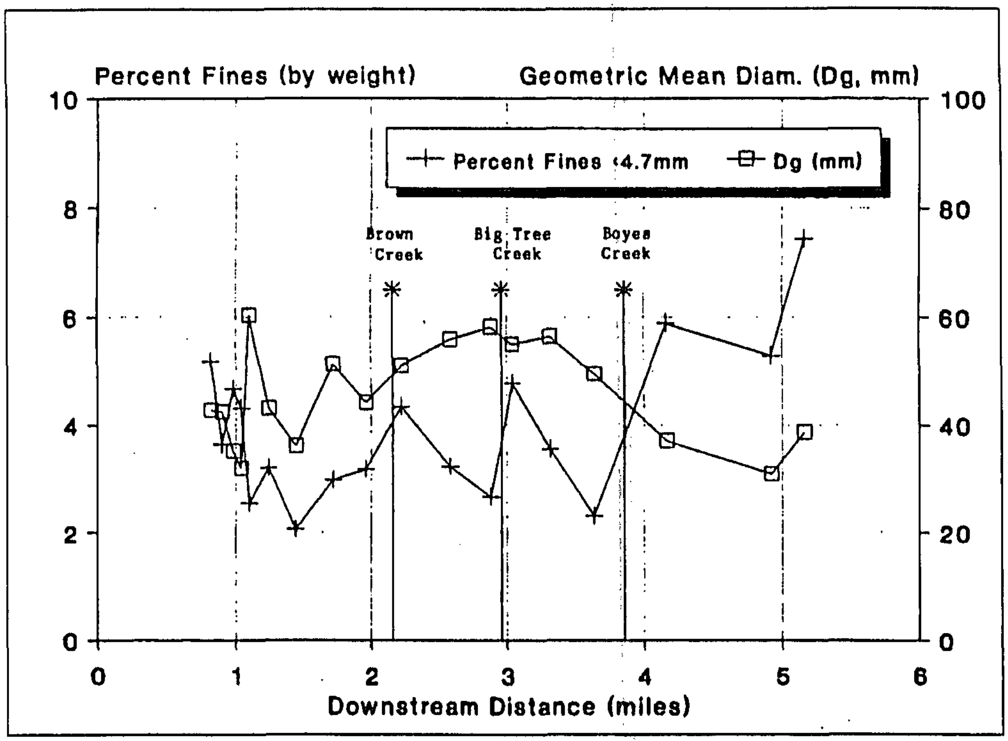


Figure 6. Percent fines and geometric mean diameter plotted versus stream distance for the Prairie Creek study reach. The three impacted tributaries are shown in their respective positions (for WY 1991).

Concluding Remark:

There is an essential relationship between hillslope processes and channel monitoring. Back to Prairie Creek, specifically the gauging station at Wolf Creek bridge (13 square miles) and Boyes Creek (1.7 square miles). Boyes Creek was monitored only during water-years 1995 and 1996. In 1995, Boyes Creek accounted for 50% of the suspended sediment at the Wolf Creek gauge and in 1996 Boyes Creek delivered about 85% of the sediment at the larger gauging site (Figure 7). Boyes Creek was subjected to pre-Forest Practice Rules logging and impacts of roads and failing landings are still fairly evident in the sub-basin. Boyes Creek was also one of the hardest hit by the Highway 101 bypass incident.

The burning question is, what is relative importance of the two landuse impacts to the recent influx of suspended sediment? If the landuses of 30 to 40 years ago are still contributing huge amounts of sediment, what does that tell us as far as focusing our current restoration efforts? Do we focus on making modern forest practices more effective, or do we use resources to go back and treat all the legacy issues still on the landscape from past practices? Sadly, I cannot give an answer today. Unfortunately, we do not have any hillslope monitoring occurring in Boyes Creek to inform us about the excessively high sediment coming out of Boyes Creek.

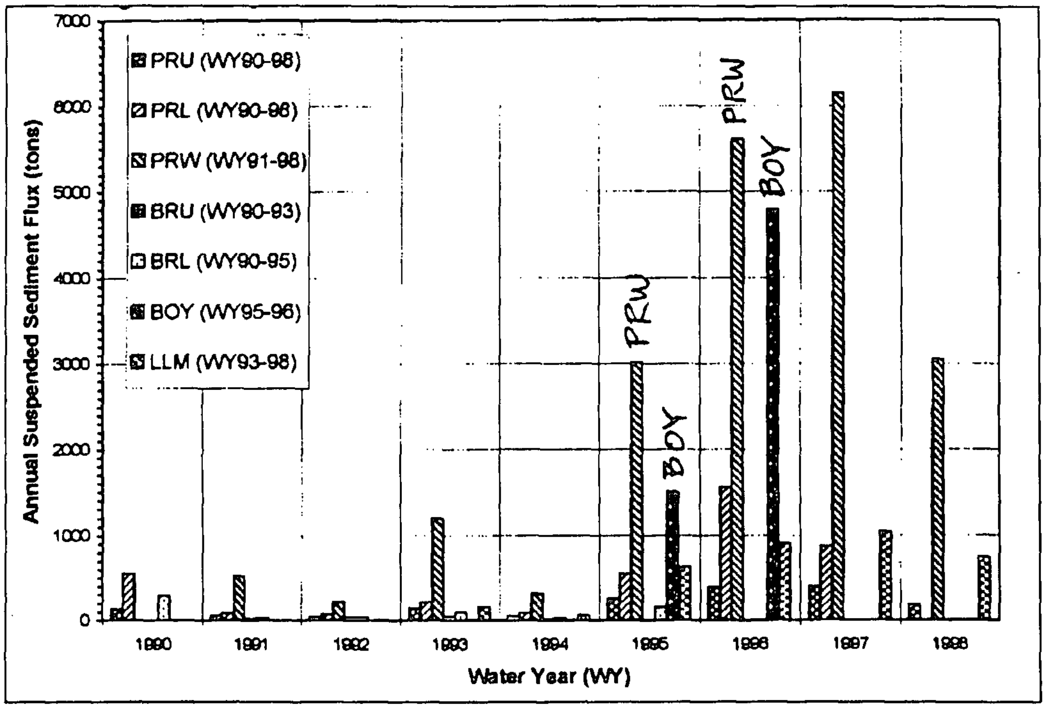


Figure 7. Suspended sediment flux at Prairie Creek basin gages: WY 1990-1998.

Know Your X's and Y's

Bill Trush, McBain and Trush, Arcata, CA.

ABSTRACT

A key to adaptive management is the generic selection of dependent and independent variables in an adaptive management monitoring plan. Having time on the X-axis is symptomatic of monitoring that provides only limited feedback for timely adaptive management. Unfortunately many recently proposed monitoring plans rely primarily on time as the independent variable. For example, long term monitoring of channel width changes from aerial photography has been proposed for assessing dam releases, while changes in channel embeddedness have been proposed to assess timber harvest. Documentation of width changes on the Y-axis (as the dependent variable, and time as the independent variable on the X-axis) is important for charting overall project success, but cannot quantitatively link cause and effect. For adaptive management, monitoring must be explicit hypothesis testing with the X-axis being the specific management prescription. Continuing with the first example, changes in channel width (the Y-axis) must be monitored as a function of the specific flow release (the X-axis).

Incorporation of physical variables into a monitoring plan generally requires biological hypotheses to evaluate risk. For example, measures of channel complexity are of limited utility unless quantitatively associated with an ecological variable such as salmonid habitat and ultimately salmonid population numbers. Less complexity risks fewer fish. Ultimately, adaptive management will require a management prescription as the independent variable and an ecological/biological measure as the dependent variable. Therefore, any monitoring program that adopts a set of physical variables inevitably adopts a set of biological variables. Both should be budgeted in a monitoring plan.

Introduction

Today's presentation will cover three subjects:

1. Hypothesis testing in general;

2. hypothesis testing regarding the efficacy of the California Forest Practice Rules (FPR's) in protecting coho salmon freshwater habitat; and

3. some of the initial work with Simpson in developing their long-term channel monitoring program and the methodology drafted by the FFFC.

The Scientific Method

"We praise the lifetime of study, but in dozens of cases in every scientific field what was needed was not a lifetime, but rather a few short months or weeks of analytic deducted inference."

John Platt in "Strong Inference"
Science Vol. 146, October 1964

Cumulative watershed effects are difficult to assess. Or so we are told. The greatest difficulty may reside in how cumulative effects are assessed rather than their actual measurement. Considering the recent rallying behind the adaptive management banner and proliferation of adaptive management monitoring plans (and workshops!), we should revisit the process of scientific investigation. Throughout most our education the time-honored scientific method has been over-simplified, and consequently miss-used. Too many graduate students' theses and dissertations (including mine) are testament to the crippling null and alternate hypotheses template often sanctioned by universities then transferred to state and federal agencies. I will argue that cumulative watershed effects are being assessed under this same inadequate framework for scientific investigation, and consequently have almost no chance of quantification. The purpose of this short essay is to advocate the scientific method, the way Francis Bacon originally intended, as an analytic framework for adaptive management and cumulative watershed effect assessment.

A typical research proposal could be as follows, stating null (H_0) and alternate (H_A) hypotheses as:

> H_0: LWD does not increase juvenile coho abundance
> H_A: LWD increases juvenile coho abundance.

The next step in this proposal would outline the experimental plan: how to quantify LWD, how to quantify coho abundance, and where/how much stream channel to sample. Last, a statistical design would be presented. Should the independent variable (LWD) be discrete or continuous? Is an ANOVA design or simple linear regression more appropriate? If the slope of the regression curve (with LWD as the dependent variable and coho abundance as the independent variable) is significantly greater than zero, then H_A would not be rejected. The discussion section accompanying this thesis would reference "the literature" to explain the observed outcome. Unfortunately (for this proposal), the explanation reserved for the discussion is the science. An hypothesis is a disciplined guess explaining an observed phenomenon. With faithful practice of the scientific method (that John Platt re-labels "strong inference"), several alternative competing hypotheses are offered as explanations for an observed phenomenon. Experimental testing is then engaged to refute competing hypotheses. Those that cannot be refuted, must be considered plausible (at least until other experimental methodologies have been refined). In the example of the thesis proposal, statistics would be used to describe the phenomenon: a probable direct relationship between LWD and juvenile salmonids. But no hypotheses would have been tested because no specific causal mechanisms were targeted as part of the experimental design. This research proposal, as intended, would get us no closer to understanding how LWD increases juvenile abundance. One could argue this research proposal should be considered a pilot study, refining an observation and/or trend, with the real science yet to come. Not all theses can be expected to experimentally (and elegantly) narrow the field of controversial hypotheses to one or two; oftentimes identification and concise description of a phenomenon are huge endeavors alone. But why is faithfully promulgating the scientific method, as originally intended by Francis Bacon, critical to adaptive management?

Scientists are supposed to figure-out how nature works, not only describe it. Are we simply weather reporters, or weather predictors? Adaptive management requires the practice of science. Quantitative understanding and timely forecasting are necessary pursuits. To achieve both, adaptive management monitoring must quantitatively link desired/undesired outcomes with specific management practices. Application of the scientific method to a properly designed monitoring plan can secure this link. As John Platt states, "Strong inference makes for rapid and powerful progress."

Selection of 'time' as the primary independent variable is symptomatic of an improperly designed adaptive management monitoring plan. This monitoring approach epitomizes a wait-and-see strategy; a management prescription is implemented, then monitored for effectiveness. With this strategy, cause and effect are separated temporally. No forecasting is involved, only reporting.

Adaptive management requires considerably more than documenting cumulative watershed effects or reporting trends. Yet both these objectives often drive contemporary adaptive management monitoring plans. Commonly, physical responses to management (re-packaged as habitat) are plotted against time or with respect to a baseline condition. For example, the percentage of fine sediment in spawning gravel (as the dependent variable) can be plotted over time or compared to reference streams. Or several independent watershed variables (e.g., soil erosivity, slope, road density, harvest area) can be measured in each sampled stream, then analyzed using multiple regression. Some independent variables are important for documenting trends in stream channel recovery: channel width, percent fines, LWD loading, and V* to name a few. These may be related to upslope conditions, to varying degrees, but would be inappropriate for an adaptive management monitoring plan because each could not be quantitatively linked to a specific management prescription. General conclusions might be reached, e.g., high road densities may be responsible for high percent fines.

All these analytical approaches may document adverse effects and chart these effects through time, but cause-and-effect has been substantially blurred to the extent that no management prescription can be directly associated with the given measured effect or trend. No identifiable and quantifiable thresholds are established. The end result is no quantitative prescription (e.g., harvest X percent less of the watershed) can be recommended.

What physical variable can be linked to ecological risks within the proper timeframe? If 50% of a watershed is to undergo even-aged management in the next decade, the dependent monitoring variable must respond within the same decade, as well as be ecologically relevant and measurable. Otherwise, management cannot adapt, and monitoring can only be used to document trends (including recovery). Suspended sediment and streamflow are probably the best two variables.

Management typically manipulates processes. Therefore, monitoring should quantify the relationship between management prescription and process. This will require getting physically and temporally closer to the cause. If roads produce the most fine sediment, then measuring suspended sediment at the roads, rather than 10 miles downstream in the channel, is needed. Then a 10 percent reduction in roads (for example) can be assigned with a quantitative reduction in fine sediment production farther downstream.

Adaptive management will also need thresholds to evaluate the significance of changes in process. These may be agreed upon from the onset, based on general literature and/or previous basin-specific studies. Refining the thresholds would be an important monitoring objective. The thresholds could relate to (1) a biological constraint (e.g., suspended sediment concentration that significantly interferes with salmonid foraging) or (2) a background level for a critical process (e.g., surface erosion rate).

Conclusion:

Application of the scientific method is critical to adaptive management. Too often adaptive management plans mirror the same deficiencies as theses: causal explanations as hypotheses are not tested. Beware of adaptive management monitoring plans that require "time" as the independent variable (the X-axis). Instead insist on making specific management prescriptions the independent variables. The dependent variable (on the Y-axis) should be physical process and biological risk variables. Long-term monitoring of channel morphology change is cumulative effects documentation, and only one aspect to adaptive management. Devising causal explanations and refuting them, through monitoring, does not lend itself to 'cookbook' monitoring methodologies.

Using the scientific method arrives at disciplined guesses at alternative, casual explanations for observed phenomenons. An experiment is designed to disprove one or more competing alternative hypotheses. This procedure is recycled, making sub-hypotheses or sequential hypotheses, to refine the possibilities that remain. Until you are left with hypotheses that cannot be disproved.

Scientists are supposed to figure out how nature works, not simply describe nature. Are we weather reporters, or weather predictors? Strong inference makes for rapid and powerful progress. So why incorporate strong inference into our protocol for revising the California FPR's?

Monitoring is hypothesis testing (long-term trend monitoring). Even documenting trends is hypothesis testing. But this is only half of what we should expect from monitoring.

California Forest Practice Rules:

Testing a management prescription such as the width of a Class 1 Watercourse and Lake Protection Zone (WLPZ) as defined in the California Forest Practice Rules (FPL's).

For a Class 1 (at least seasonally fish-bearing) stream channel with hillslopes of less than 30% the WLPZ is 75 feet. Is this width adequate in promoting and maintaining "good" aquatic habitat? What width is needed to maintain habitat? How do we apply strong inference to test the efficacy of this rule? What do we attempt to disprove? Start with the reasons listed in the FPR's as the beneficial reasons for having a riparian buffer (use these as the alternate hypotheses).

Focus on fish values. How can a 75-foot buffer protect fish values in a stream? Do we monitor the fish? I wouldn't. I would look at what is needed to maintain the standing crop of both instream LWD and future LWD recruitment from riparian zones (a desired process to maintain).

What are the alternate, causal explanations to how the standing crop of LWD is maintained within the 75-foot width?

First must ask, "What are the processes (and rates) that recruit LWD to the stream from the riparian vegetation"?

1. Windfall.
2. Channel migration.
3. Upstream sources (transport).
4. Decay rates.
5. Piece location, size, and volume.
6. Regrowth of riparian trees.

Will not arrive at an answer by just inventorying LWD and counting fish, at least in evaluating the 75-foot buffer width in maintaining beneficial uses for salmonids.

What is real adaptive management and monitoring? Adaptive management is not monitoring long-term trends (cumulative effects documentation). It is hypothesis testing with a biological parameter as the preferred dependent variable (Y-axis) and a management prescription or a FPR as the independent variable (X-axis). Or if a physical variable is used on the Y-axis, it must have a fairly direct link to the biological. Currently the best variable is probably fine sediment in spawning gravels.

To provide more detail on how to test a FPR let's examine the number of cross drains (maximum spacing) on an unpaved forest road as the dependant variable (X-axis) and plot versus the annual suspended sediment production on the Y-axis. With a suspended sediment rating curve, examine the change in suspended sediment as the spacing or number of drains is varied.

What would be the specific management recommendation?

1. No increase in % fines after 10 years = use current FPR, but continue to monitor? Lots of explanations to why, which may vary from your personal biases or interests.

2. If suspended sediment increases by X%, there may be lots of factors involved in the "why"?

3. If levels decreased, also lots of possibilities; including favorable weather, too short of monitoring period, stable geology, or possibly FPR is adequate. Wouldn't know if decrease could have been even greater with more cross drains.

First symptom of non-adaptive management is when X = time. Fine for assessing long-term trends or documenting cumulative effects, but not for adaptive management.

Mono Lake example: Rush Creek below Grant Lake

Monitoring channel width versus time. No processes on Y-axis such as flow quantity, duration versus timing of flow (managed releases from Grant Lake). The correct prescription is to monitor natural function or processes as related to a specific management prescription. In the Rush Creek case the independent variable was an amount of flow at a known duration at a specific time. Made the link from the physical to the biological to the management prescription by getting Los Angeles Water and Power to release a flow on average once a year to mobilize the D-84 particle size, that is restore (or mimic) the natural processes that form and maintain desired channel features. Relied on processes versus the management prescription.

Simpson's Monitoring Plan:

Get away from examining mean values, these never exist in nature. Should examine the variance in physical parameters as a measure of ecosystem health. Variation in thalweg profile was one of the first parameters measured in Simpson's channel monitoring program. A healthier thalweg profile should have more variation, thus a bumpier line when plotted. Also what is forming the pools in various channels may reveal distinct fingerprints or signatures for different channel morphologies.

Want to also evaluate the slope and intercept of the thalweg too. Overall, is the channel through the monitoring reach aggrading or degrading? Because of heavy past aggradation there was evidence that the channel had already experienced considerable downcutting and narrowing.

The placement of the regression line was important too. Because the pools may temporarily store sediment even when the overall channel is not aggrading, we decided to fit the regression line through the riffle crests. We also installed cross sections along the monitoring reach, anticipating the channel would continue to narrow as stored sediment continued to be transported and natural processes were restored. On larger storms sediment was also deposited on the terraces and bars, building up the banks and confining the channel (another desired and anticipated geomorphic response to decreasing sediment load).

Initially, the idea was to resurvey monitoring reaches after a storm with a five-year or greater recurrence interval. However, Simpson decided to remeasure some of the variables inbetween larger events to evaluate changes in channel width and thalweg due to gradual winnowing of fines from pools during smaller storms.

Lowell mentioned that the monitoring program may also serve some short-term uses too. I would agree with him cautiously. If after several years of moderate storms, there was evidence of aggradation and widening of the channel, the next step should be to look (at least) up-channel for mobilization of stored sediment. If no obvious signs were detected then the next step would be to look upslope at the roads and hillslopes. This process may not get towards a FPR's change, but maybe a future management change. This process may have utility in smaller (third-order or less) watersheds, but I would not recommend it for Redwood Creek or the Mad River (where cause and effect are too separated, spatially and often temporally).

Summary:

Beware of adaptive management monitoring plans that require "time" as the independent variable (the X-axis). Instead insist on making specific management prescriptions the independent variables. Strong inference is adaptive management.. Long-term monitoring is generally cumulative effects documentation, and has limited utility as adaptive management. Do not want "cook book" rules for adaptive management monitoring. Coming up with causal explanations and refuting them does not lend itself to a cookbook, do not fool yourself. Must attempt to make the biotic variable link to the channel variable, that in turn links to the management prescription. If not, present the idea of restoring processes in that particular ecosystem, such as riparian buffer function (Y-axis) and how that relates to a management prescription (X-axis).

Field methodology of using stream geomorphic characteristics for long-term monitoring.

Matthew House, Simpson Timber Company, Korbel, CA.

ABSTRACT

Land management practices can influence the physical habitat of aquatic ecosystems. It is important, however, to separate management effects from natural variability and to understand the effects from large storm events on the productivity of streams and physical habitat parameters. I will describe a methodology that was developed to 1) document changes in stream morphology in selected aggradational reaches; 2) collect data that will provide a better understanding of channel processes and stream dynamics in streams and 3) use long-term trends in key channel variables to assess changes in sediment delivery due to hillslope processes. Channel variables that will be addressed or later computed in the monitoring protocol include: bankfull and active channel widths, thalweg elevations, surface channel bed particle size distributions, maximum residual pool depths, channel cross-sections, pool/riffle ratios, planform radius of curvature, and large wood volumes and size class distributions.

Reach Selection and Length

Long-term channel monitoring reaches are typically located in low gradient channels (1.5 % or less) with alluvial, erodible banks. These channel reaches are referred to as depositional areas. Depositional reaches were first identified by plotting the longitudinal profile of the stream channel of interest (Figure 1). The length of the monitoring reach is scaled to stream size, and is generally three meander wave lengths (or about 25- 30 bankfull channel widths).

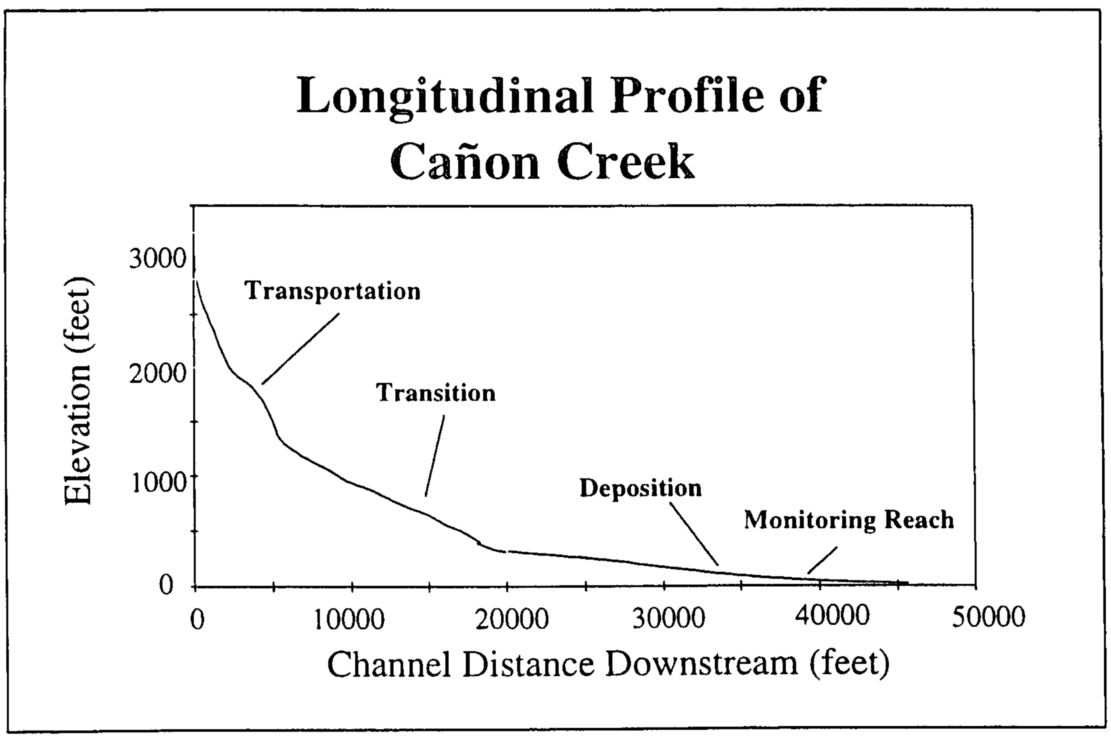


Figure 1. Longitudinal profile depicting reach site selection for long-term channel monitoring.

Key Variables

The key variables measured by Simpson includes a subset of the suite of variables suggested in the FFFC's draft of the long-term channel monitoring protocol. Statistical analyses will be conducted only on the first three variables listed. Other variables include residual pool depth, planform radius of curvature, pool/riffle ratio, residual fine bedload volume in pools (V*), and spawning gravel composition.

Simpson conducts remeasurement of the key variables every other year, or the summer following a winter where a storm has occurred with a recurrence interval greater than five years.

Key Variables:

1. Bankfull and active channel widths.
2. Thalweg profile
3. Pebble counts
4. Channel cross-sections
5. LWD and riparian inventory
6. Others

Equipment List:

The following is a list of the equipment required to establish a monitoring reach and collect the data required for the list of key variables:

1. Automatic level
2. Tripod
3. Leveling rod
4. 300' tapes (2)
5. 50' tape
6. Diameter tape
7. Rulers
8. Compass
9. Rebar
10. Hammer
11. Shovel
12. Cement
13. Carriage bolts
14. 12" spikes
15. All-weather field notebooks
16. Flagging

The use of the automatic level and the surveyor's rod is the most technical aspect of the field protocol. Crews experienced in basic survey techniques are preferred. A total station is an appropriate alternative to using the autolevel and would probably be more time-efficient.

Laying the Center Tape:

Laying the center tape is an important first step because many of the other variables are measured and recorded with respect to the center tape. The center tape also provides the station locations up the channel for mapping purposes. The tape generally follows the direction of the channel meander (Figure 2). The beginning of the tape is held in place with a length of rebar driven into the channel bed. Rebar is also used to secure the center tape at meander bends or any turning point in the tape. A short section of old garden hose slid over the rebar protects the tape from wear and a clamp is used to hold the tape in place. Simpson's field crews usually lay out two, 300 foot tapes at a time. This is often the length a crew can completely sample in a day.

Once the center tape is set, basic channel dimensions are measured and recorded. The azimuth of each straight section of tape is measured. Station numbers (in tenths of feet) are recorded at any turning point in the center tape. Rebar stakes used for turning points can also be used for temporary bench marks (TBMs) if they are very stable. Twelve inch spikes driven into a large LWD or rootwad can also serve as TBMs. Station number and elevation of each TBM is recorded on an aluminum tag and secured to the rebar or spikes for future reference.

At the lower end of the reach, assign one of the temporary benchmarks an arbitrary elevation of 100.00 feet, then reference (shoot the elevation) the rest of the temporary benchmarks back to the first. "Close the loop" frequently (at least daily) to catch any surveying or note recording mistakes in a timely fashion.

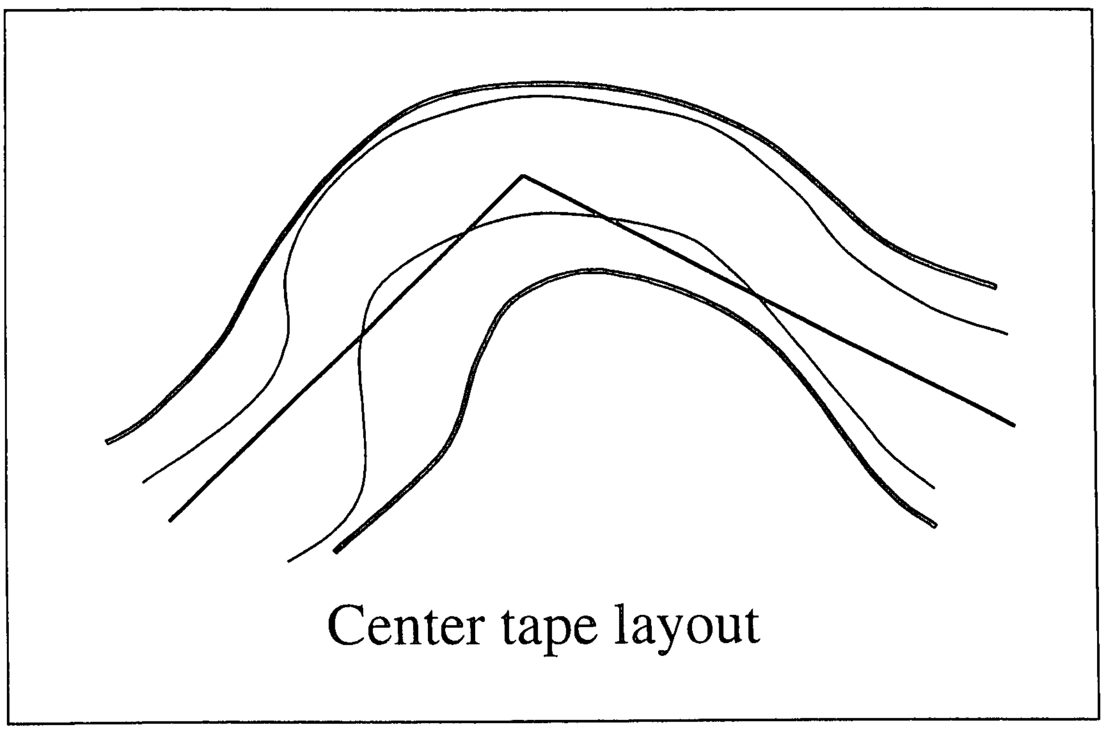


Figure 2. Center tape layout. Middle line represents the center tape, the broken lines are the active channel margins, and the solid outer lines are the bankfull channel margins.

Two permanent benchmarks are also established; one at the lower and one at the upper end of each monitoring reach. The second permanent benchmark serves primarily as a backup in the event one is disturbed or is washed away in a flood. The benchmarks consist of a carriage bolt set in concrete (sack of redimix poured into a one foot diameter, two foot deep hole). Make sure to locate the permanent benchmarks well above and away from the bankfull channel because this will be the long-term reference marker for the elevation surveying of the monitoring reach. When established, shoot the elevation of the permanent benchmarks, as well as carefully describe their location in the field notes and draw a detailed sketch too.

Measuring Channel Dimensions:

Identifying bankfull and active channel margins is one of the more subjective measurements of the long-term channel monitoring protocol. The active channel is defined as a base winter-flow and bankfull is a flow with a recurrence interval of about 1.0 to 2.0 years. There are some criteria available to reduce the subjectivity of these measurements:

1. Active channel margin indicators – exposed cutbanks, exposed alder or willow roots, edge of annual vegetation, lower extent of lichens and mosses, or slight breaks in bank angle on gravel bars (as well as break in substrate particle sizes).

2. Bankfull channel margin indicators – edges of perennial vegetation, top of exposed point bars on meander bends, or significant change in bank slope (and particle sizes).

Originally, all channel width measurements were made parallel to the center tape. Problems arose when taking width measurements at meander bends, the measurement would sometimes extend up the channel and encompass multiple active or bankfull margins. The current protocol calls for taking the shortest distance between bankfull channel width (Figure 5). Simpson employs a random start, then a systematic sample every ten feet. ***Editor's Note:*** The second draft of the FFFC protocol calls for a random start, a systematic sample every ten feet, as well as a measurement at any noticeable change in width (for mapping purposes).

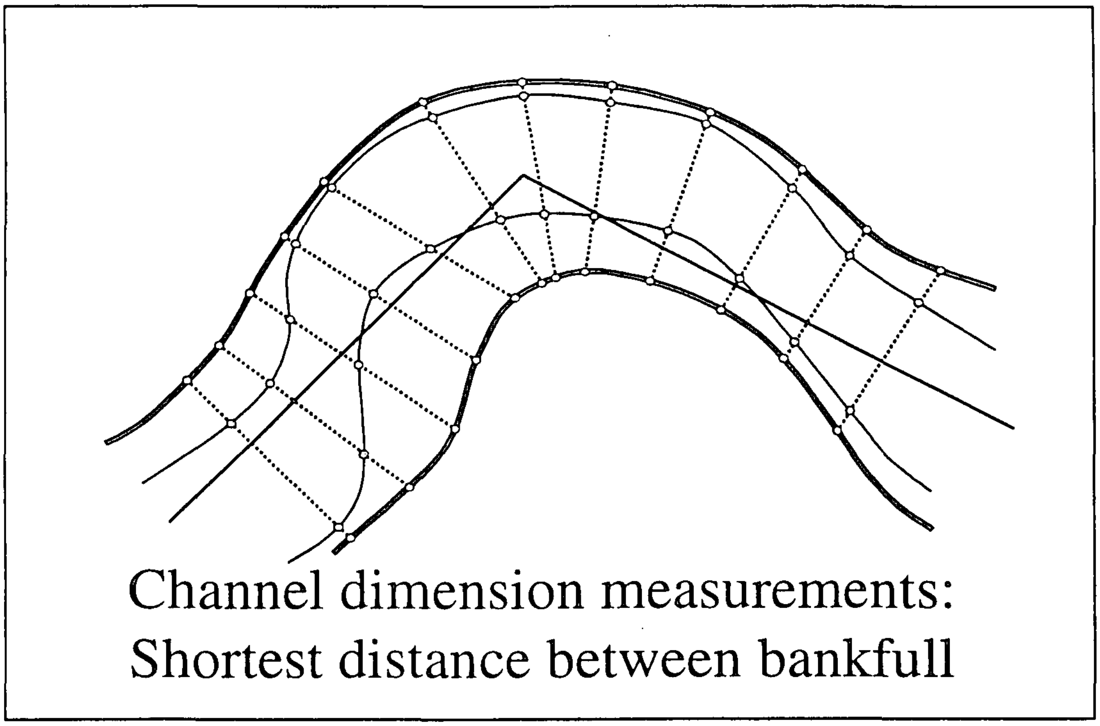


Figure 5. Channel dimensions measurements: shortest distance between bankfull. Note: Dotted lines represent the channel width transects.

Channel width measurements are most easily conducted with three people: a person at each bank stretching the tape and a person in the middle lining up the cross section tape at the ten-foot intervals along the center tape, as well as recording data. At any station, the active channel width was measured first, and then the bankfull width. The azimuth of each cross section was also measured and recorded for mapping purposes.

When an "island" is encountered where the top of the bar is below the bankfull elevation, measure across the entire channel, then subtract-out the width of the "island" feature. In the case of a large side channel, a second center tape may be laid up the side channel directly off a station of the primary center tape. Record the azimuth of this secondary center tape.

Thalweg Profile:

In order to test for statistical differences, Simpson measures thalweg elevations at locations selected by a random start, then systematic sampling every ten feet. (***Editor's Note:*** The second draft of the FFFC protocol calls for a random, systematic sample every ten feet, as well as a measurement at any noticeable change in thalweg depth). Ignore deep pockets of isolated water. At each center tape location, measure and record the perpendicular distance to the thalweg location (also record as either left or right bank from the center tape) (Figure 6).

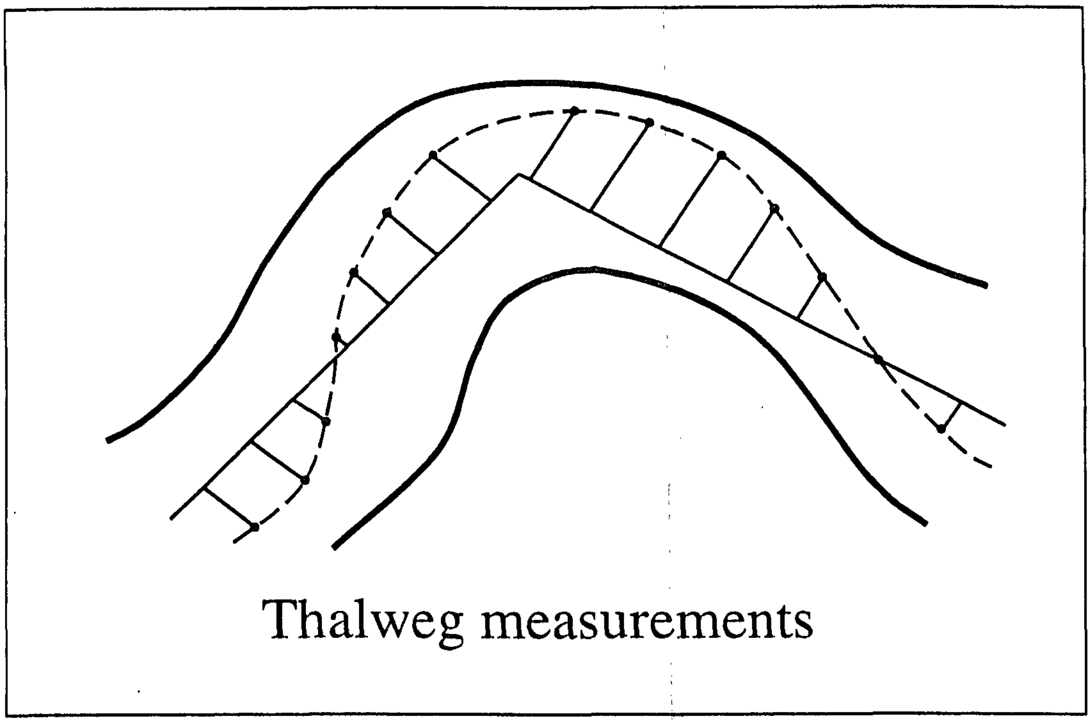


Figure 6. Location of thalweg measurements off center tape. Dotted line represents the thalweg.

Pebble Counts:

Taken in straight channel reaches of three to four bankfull channel widths in length. The sites usually coincide with the cross-over of the thalweg profile, where the thalweg switches location from one bank to the other (Figure 7). These areas generally have uniform cross sections and are relatively resistant to adjustments in channel width.

Sample pebbles from within the active channel width. Based on riffle length, divide the riffle into ten equally-spaced transects (Figure 8). For example, along a 100 foot long riffle, transects would be spaced ten feet apart. Randomly select the location of the first transect, then evenly space the remaining nine transects. Along each transect, collect 15 pebbles at roughly evenly-spaced intervals for a total of 150 pebbles. A pebble is selected by blindly moving one's finger off their boot-tip and taking the first pebble touched. Measure the diameter of the secondary axis of the pebble. The secondary axis is the diameter in which the pebble would fit through a sieve.

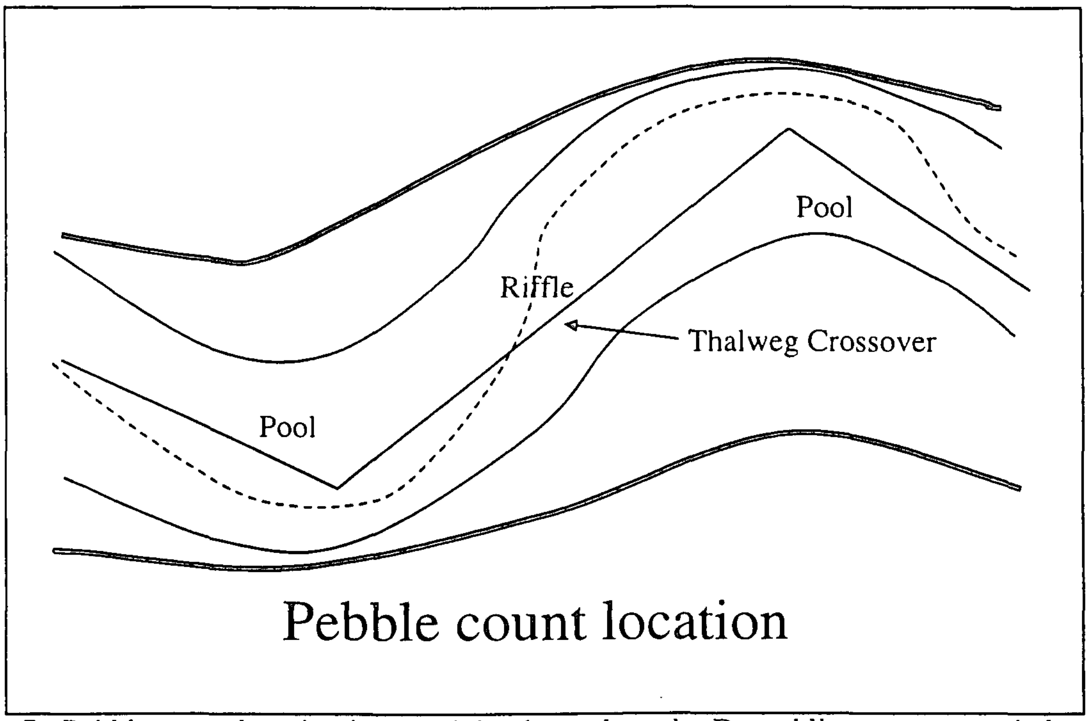


Figure 7. Pebble count location in a straight channel reach. Dotted line represents thalweg. Note: the location of the thalweg cross-over.

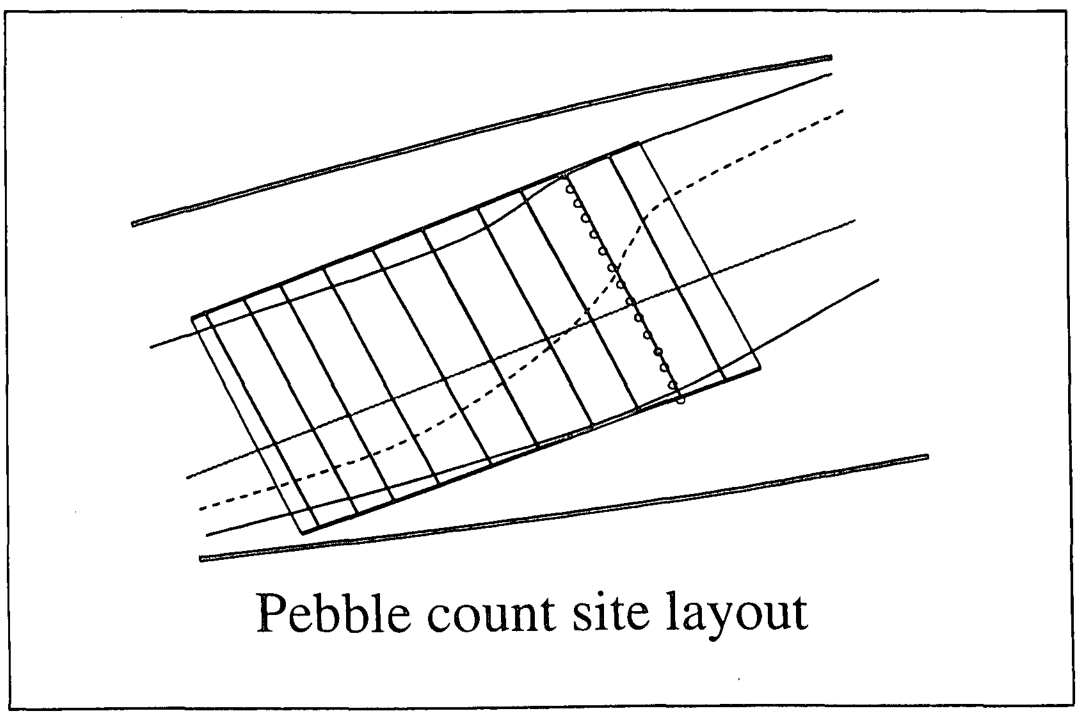


Figure 8. Pebble count site layout consisting of ten, evenly spaced transects. Dotted line represents thalweg.

Cross Sections:

Cross sections are located at bend apexes and at straight channel reaches (Figure 9). On straight reaches survey from just beyond the bankfull channel margins, generally at the location of the thalweg cross-over. At bend apexes, cross sections are surveyed from valley wall to valley wall. Cross sections are established to monitor the development of the flood terraces. Establish cross section rebar pins at both ends of the cross section. Stretch a tape across the channel and secure the 0.0' end of the tape to the left bank pin. Take an azimuth along the cross section tape from the left bank pin. Survey the bed elevations at stations along the tape using the nearest TBM as an elevation reference. Take measurements at a maximum of five foot intervals, or at smaller intervals to catch major topographic change along the cross section.

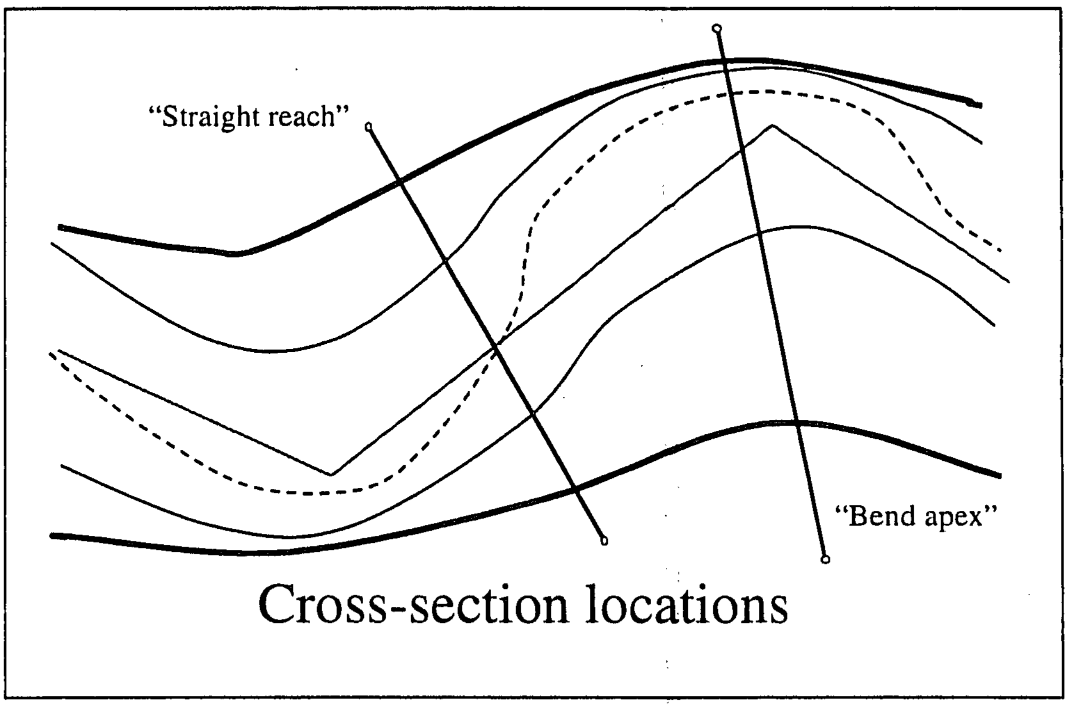


Figure 9. Cross-section locations for long-term channel monitoring.

LWD and Riparian Inventory:

For each piece of qualifying LWD (at least 6" minimum diameter and six feet in length) measure the following:

1. total length;
2. maximum and minimum diameter;

3. distance center tape (station #);
4. distance from center tape (left or right bank);
5. azimuth; and
6. type (hardwood or conifer) or species.

LWD inventories only conducted during the initial channel survey. Simpson plans on periodic remeasurement of LWD in channel monitoring reaches, but is waiting for the completion of the LWD and Riparian Inventory protocol currently being developed by the FFFC. Hundred-percent LWD inventories have also been conducted by Simpson along the entire reach of anadromy in most streams selected for long-term channel monitoring.

The following characteristics of riparian vegetation were measured and recorded:

1. Location along center tape;
2. species;
3. diameter at breast height (dbh); and
4. distance from bankfull channel margin.

Clarification Questions:

1. *How long does it take your crew to complete a reach of stream?* Ideally, you would use a five-person crew: three persons to measure channel dimensions and two persons to conduct pebble counts and LWD/riparian inventories. Our crew can usually complete a 600 foot reach per day (a long day). So for a third to fourth order channel reach of 1500' -3500', the entire field effort would be approximately three to six days.

2. *When do you intent to analyze with the data, do you have a target?* We're just starting to analyze the data with the help of Trent McDonald and foresee additional changes to the protocol to improve the statistical rigor.

3. *Do you think that ten foot intervals in the measurement of channel widths are needed or could distance between measurements be increased?* Some of the statistical analyses will go into this discussion, I feel there are circumstance where measurements could be taken at greater intervals, but then there's always the chance you might miss a unique feature or change in width (for mapping purposes).

4. *Currently you're only conducting pebble count within the active channel, any thoughts about conducting pebble counts on the bar tops as well?* These areas were sampled when we initially started the channel monitoring protocol. However, we found that the riffles were areas with a more uniform distribution of substrate, whereas on bars LWD or other obstructions would cause localized settling of fines. Often these areas are very messy to sample, especially with deposition of fines over the gravels – what do you sample? The fines or the substrate?.

5. *Taking the thalweg measurement every ten feet, do you fell you miss some of the actual variability of the profile by not also measuring at distinct changes?* We looked at this in the analysis and Trent will discuss it next.

6. *Is there any set protocol for how and where you place the turns of the center tape?* The center tape should stay within the bankfull channel margin, but does not necessarily follow the wetted channel. Actually, you want to minimize turns in the tape and have it run straight for as long as possible.

7. *The center tape is used so that all the features can be mapped, so if a total station was used there would be no need for the tapes?* Yes, and the use of a total station would probably save time.

8. *How long did it take you to sample one of the monitoring reaches?* Usually 600 feet of channel could be sampled a day, and Simpson's reaches range from 1,500 to 3,500 feet (about three to six days). That is the time required to just collect the data.

9. *What is Simpson doing to link the physical data to fish response?* We're doing other monitoring in these reaches, but we haven't made any links to the physical channel response yet. We're doing a modified Hankin/Reeves population estimate for young-of-the-year coho and 1+ and 2+ "trout" (steelhead and cutthroat) on several of the streams with established long-term channel monitoring reaches. In addition we have out-migrant traps in several streams where we plan to quantify the different habitat conditions (LWD, habitat complexity, gradient, etc) between streams and compare them to the fish populations both summer and winter and ultimately determine an over-winter survival estimate.

An Analysis of Stream Monitoring Data

Trent L. McDonald, Western EcoSystems Technology, Inc., Cheyenne, WY.

ABSTRACT

Simpson Timber Company contracted with Western EcoSystems Technology, Inc. for assistance analyzing Simpson stream monitoring data. In my presentation, I describe the statistical methods and results of an analysis of data from selected streams on Simpson property. My objectives are the following: 1) to describe the Simpson analysis, 2) to present results from typical or "case study" streams, 3) to describe Simpson's efforts to estimate measurement or crew-to-crew variation, and 4) to point out that parts of the analysis were not straightforward. Future analysis of the Simpson data will incorporate additional data (annually) and changes in field protocols.

Analysis of the Simpson data focused on three variables: 1) thalweg elevation, 2) channel width, and 3) substrate (pebble) size. Within a single stream, yearly thalweg profiles were analyzed for changes in mean and residual variance. Mean thalweg elevation was analyzed using a 1-dimensional spatial regression model. Residuals from the regression were analyzed for change using a modified version of Levenne's test (spatially adjusted). Channel width was analyzed for change in mean (across years) using a spatially adjusted analysis of variance (ANOVA) model. Pebble size distributions were analyzed for shifts using Wilcoxon and Kruskal-Wallis non-parametric tests.

At one stream, thalweg profile was observed to be nonlinear and to change curvature between years. At another stream, overall height of the thalweg was identical across years even though pools changed position and depth. Analysis of the thalweg residuals generally showed decreases in variance across years. Analysis of pebble size generally showed increases in the frequency of large pebbles. These results were developed using at most four years of data and must be interpreted with the knowledge that the field protocol was in development during the study.

This presentation of the statistical analyses of the data collected by the methods just described will follow this outline:

Below, I cover statistical methods for analysis of thalweg elevation, a correction for spatial correlation, analysis of channel width, and analysis of pebble counts. Results of these analysis on selected Simpson streams is also given.

Methods

Thalweg elevation

Thalweg elevation was analyzed for change in mean and change in variance. Change in mean thalweg elevation reflects long-term or long-range changes. Change in variance of the thalweg reflects changes on shorter range or finer scale. The basic data collected in the field were the data pairs, (d_i, y_i), where d_i represents distance from upper end of reach and y_i represents elevation of the thalwag at d_i. A typical thalweg profile appears in Figure 1.

The analysis for change in mean thalweg elevation fit a third order polynomial to the (d_i, y_i) pairs. Year of data collection was incorporated into the model as a 0-1 "dummy" variable. The estimated third order polynomial had the form:

$$
\begin{aligned}
\mathbf{E}[\mathbf{y}_i] = \beta_0 + \\
&\beta_1 \mathbf{x}_{1,i} + \beta_2 \mathbf{x}_{2,i} + \\
&\beta_3 \mathbf{d}_i + \beta_4 \mathbf{d}_i^{\,2} + \beta_5 \mathbf{d}_i^{\,3} + \\
&\beta_6 \mathbf{x}_{1,i} \mathbf{d}_i + \beta_7 \mathbf{x}_{1,i} \mathbf{d}_i^{\,2} + \beta_8 \mathbf{x}_{1,i} \mathbf{d}_i^{\,3} + \\
&\beta_9 \mathbf{x}_{2,i} \mathbf{d}_i + \beta_{10} \mathbf{x}_{2,i} \mathbf{d}_i^{\,2} + \beta_{11} \mathbf{x}_{2,i} \mathbf{d}_i^{\,3}
\end{aligned}
$$

Where d was distance from top of stream and x_{ij} was the dummy variable for year "i" observation "j" (i.e., 1 if observation "j" was from year "i", 0 otherwise). The residuals about this regression line were assumed to be spatially correlated. All tests associated with the regression were corrected for spatial correlation (see below).

Changes in mean height were assessed by testing for changes in the year*distance coefficients in the model. A third order polynomial was chosen because lower order polynomials are not sensitive to certain types of changes in thalweg height. For example, it is possible for a stream's thalweg elevation to change in its second derivative (curvature) but remain the same height and therefore go undetected by a linear line. This situation is depicted in Figure 2.

The analysis of thalweg residual variance performed a modified version of Levene's test on the observed residuals obtained from the third order polynomial fit above. Levene's standard test was modified to account for estimated spatial correlation in residuals of the model. Levene's test viewed residuals from each year as separate samples and tested for differences in absolute deviations from the sample means among year. Typical residuals analyzed for change in variance are shown Figure 3.

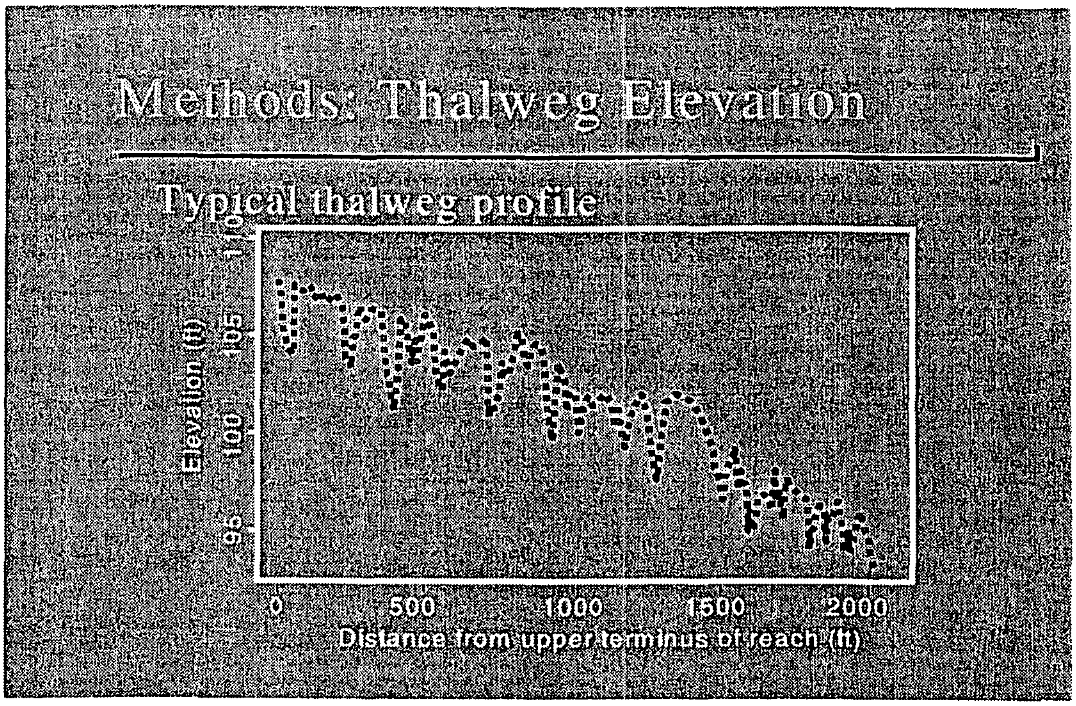


Figure 1. Thalweg profile from one of Simpson's long-term monitoring reaches.

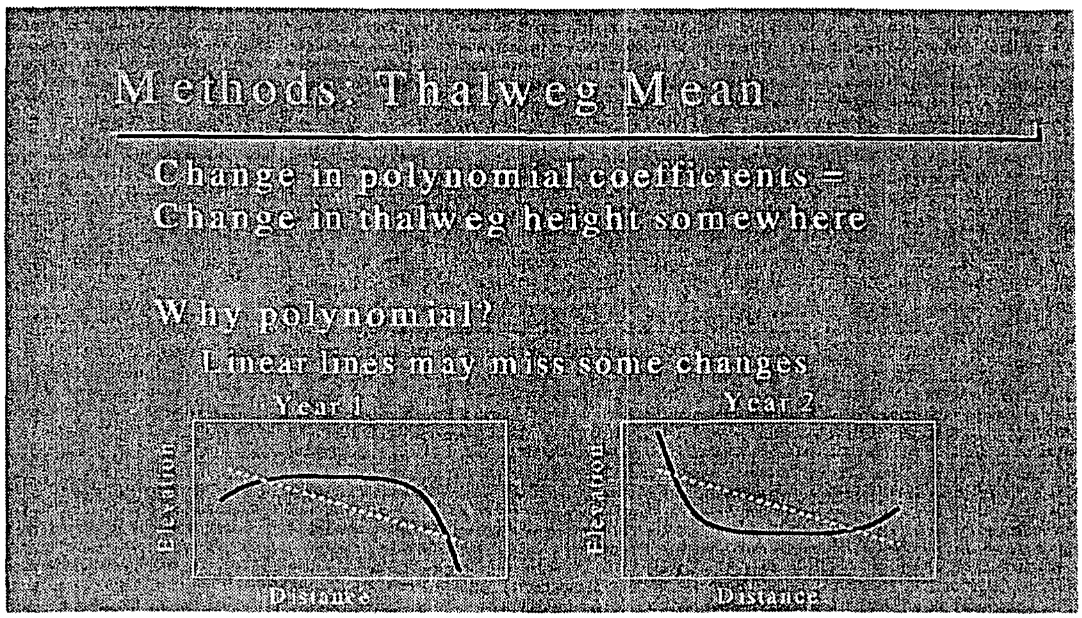


Figure 2. Figure illustrating the need for higher order polynomials. Thalweg elevation (red line) may change in curvature between years but go undetected by a lower order polynomial such as a linear line (yellow).

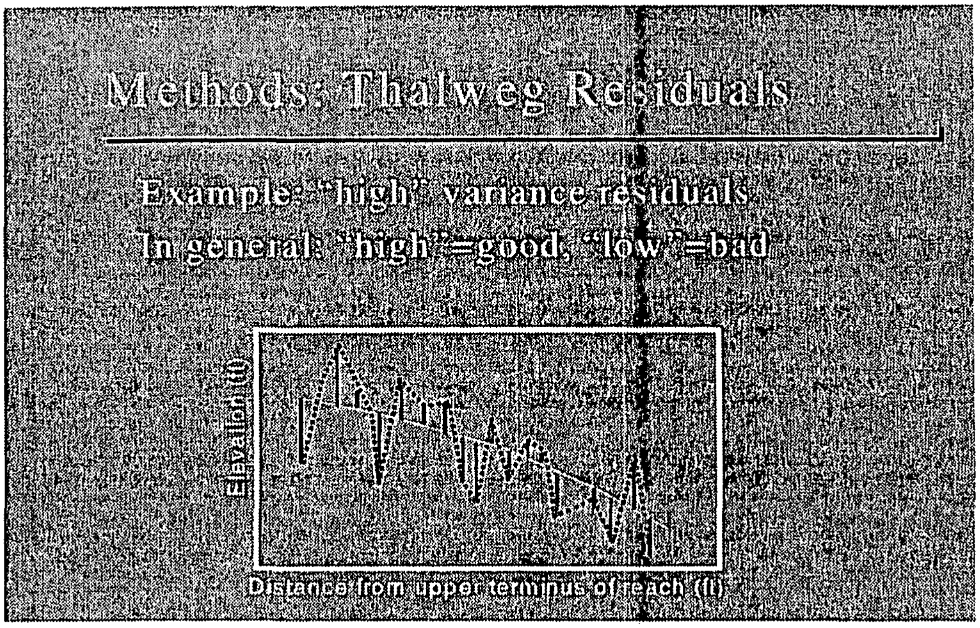


Figure 3. Thalweg profile with residuals shown.

Spatial correlation correction

Measurements taken close together in space tend to be correlated. Thalweg elevations were typically taken every ten feet and were therefore potentially correlated with one another. This section describes one method for correcting coefficients and computed p-values to account for spatial correlation. If this correction were not done, naïve p-values assuming independence would be too low because sample size (i.e., n) does not accurately reflect the amount of information present in the analysis.

The spatial correlation correction is facilitated through the use of a 1-dimensional geostatistical model. Geostatistical methods, usually applied in two dimensions, are carried out in three steps. First, ordinary least-squares estimation is preformed. Second, auto or spatial correlation remaining in the residuals of the least squares analysis is modeled. Third, weighted least-squares estimation is preformed to adjust coefficients and consequently p-values. Step 1 was described above (e.g., fit a third order polynomial). Steps 2 and 3 are described below.

Correlation in least-squares residuals are modeled by computing the values, $z_{ij} = (r_i - \mu_r)(r_j - \mu_r) \div s_r^2$, where r_i is the i-th thalweg residual, μ_r is average thalweg residual, and s_r^2 is the sample variance of residuals. The z_{ij} are then plotted against h_{ij} (= distance between points residuals i and j) and smoothed using a kernel scatter plot smoother. A non-linear model is then fit to observed z_{ij} and an estimated variance-covariance matrix for the residuals is computed.

Step 3 of the spatial correlation correction method uses the estimated variance-covariance matrix (from step 2) as a "weight" matrix in an ordinary weighted least squares estimation problem. From this weight matrix and the design matrix, coefficients and their standard errors are adjusted for spatial correlation among residuals. T statistics (estimate / standard error) were recomputed and updated p-values computed.

Channel width

Channel width, measured as either bank full or active channel, were analyzed for changes in mean using ANOVA methods. The 1-way ANOVA methods viewed year as the grouping variable and adjusted results for estimated spatial correlation.

Pebble Count Sizes

Pebble size measurements were taken by measuring pebble size along transects at specific sites. Due to the large distance between pebbles and relatively small size of the pebbles, individual width measurements were treated as independent. No correction for spatial correlation was computed, as was done in the analysis of thalweg elevation and channel width. The distribution of pebble sizes was analyzed for change across years. Shifts and certain changes in shape were tested using the Wilcoxon and Kruskal-Wallis non-parametric procedures. The observed distribution of pebble sizes each year was plotted to aid interpretation.

Measurement Error

Two types of measurement error can occur during stream monitoring activities; 1) repeated measurements by same crew will not yield exact the same results (i.e., within crew variation), and 2) measurements of the same quantity by two different crews will not yield the same results (i.e., among crew variation). Among crew variation is more critical because it is likely bigger than within crew error and it effects comparison of survey results over long-term application of the methods.

In 1998, Simpson agreed to a study of the measurement error inherent in channel monitoring measurements. Between crew variation was estimated by computing variation and mean differences between two independent crews measuring the same quantity in the field. Each crew was out of sight of the other; however, each crew was familiar with the other crew's general mode of operation.

Results

Thalweg Elevation

On one study stream, curvature (trend in quadratic component) changed between 1995 and 1996. At two other study streams, overall height of the thalweg was similar across years and appeared linear. Closer inspection of the thalweg profiles showed that some pool locations and depths changed on every study stream.

Thalweg Residuals

Analysis of thalweg residuals generally showed decreases in variance across years. Thalweg residual variance at one study stream decreased from 1995 to 1996, but remained constant through 1997. At two other streams, thalweg residual variance decreased between 1996 and 1997.

Channel Widths

The following table shows estimated average bankfull and active channel widths for two streams between 1996 and 1998. Average bankfull width at stream 1 increased from 47.4 feet to 62.1 feet between 1995 and 1996, but remained constant thereafter. A major flood occurred in stream 1 between sampling in 1995 and 1996 which might explain the increase in average bankfull width.

Estimated Channel Widths (feet)			
Creek #	**Year**	**Mean Bankfull Width (s.e.)**	**Mean Active Width (s.e.)**
#1	1995	47.4 (4.68)	29.5 (2.64)
	1996	62.1 (6.00)	47.2 (2.36)
	1997	67.1 (6.66)	50.6 (4.11)
	1998	70.9 (5.91)	58.1 (3.82)
#2	1996	56.2 (3.42)	38.5 (3.15)
	1997	57.0 (5.13)	37.8 (3.40)
	1998	64.7 (4.54)	43.0 (2.58)

Pebble Counts

Analysis of pebble size distributions generally showed increases in the frequency of larger pebbles.

Measurement Error

The following table contains average crew-to-crew differences in bankfull and active channel measurements. Overall, both crews cancelled each other (i.e., same number of positive differences as negative) and arrived at mean difference less than 2.9 feet for both measurements.

Mean Crew Differences								
Stream #	**Bankfull Channel Widths**				**Active Channel Widths**			
	Mean Diff. (ft)	**Lower 95%**	**Upper 95%**	**Correlation**	**Mean Diff. (ft)**	**Lower 95%**	**Upper 95%**	**Correlation**
#1	4.3	1.8	6.8	0.86	2.2	-1.1	5.5	0.64
#2	4.6	2.0	7.3	0.87	3.9	1.9	6.0	0.71
#3	0.9	-1.5	3.3	0.85	0.5	-2.6	3.6	0.74
#4	2.0	1.1	2.8	0.85	2.9	1.4	4.3	0.36
Average	**2.9**			**0.857**	**2.4**			**0.61**

Discussion

Quality monitoring programs contain the following four features; 1) field methods must be simple, 2) monitoring programs must produce regular reports, 3) field sampling must encompass many different places, and 4) monitoring activities must fuel more intensive research, but monitoring activities can not *be* research. Simple field methods assure that the data collection is repeatable across crews and is relatively cheap in order for long-term implementation to be feasible.

Clarification Questions:

1. *Why did you analyze the variables that you selected and not looked at others, such as residual pool volume or a sequence of depths (flow independent)?* One of the motivations to analyze change in thalweg residuals was it was fairly simple and objective (to fit a least squares line). Other pool attributes were considered, yet just the subjectivity involved with accurately defining the boundary of a pool (volume and depth).

2. *What is the biological significance of changes in the best-fit line of the thalweg residuals, how is Simpson going to use changes in curvature of the best-fit lines as an indicator of stream health?* Simpson is relying on the assumption that more variation in the thalweg profile and residuals is good, as the channel improves and the diversity of habitats increases these should be detected by increases in the thalweg residuals. Comment by Madej: As a biological indicator it may be better to de-trend the data and just look at pools as a population of water depths below the elevation of the riffle crest (downstream control), then changes in the depths of a single pool don't shift the slope of the entire least-squares line. McDonald: does this method rely on a definition of riffle crest? Madej: yes, it is very important, and

that is why we don't take measurements on a random, systematic approach as Simpson because we want to accurately locate and measure the elevation of the downstream control, as well as the maximum depth of any given pool. To statistically analyze the data we use a program to interpolate the points in-between and then we draw a sample from this universe of depths. Diller: we followed that approach, which was recommended by Trush, but then changed our approach when the statistician showed. How can you statistically analyze data that were subjectively collected? Madej: we measure the depths at the breaks such that the depths interpolated between two measured depths accurately depicts the channel profile, then we set a systematic sample every two to five meters (depending on stream size).

3. *For any given pool or reach of stream there must be a boundary of the maximum depths, how do you know what this is, and is it possible that the amount of change that can occur would never be enough to be detected statistically?* If there was some maximum depth,

4. *This question is probably more towards Lowell, when you detect large changes in active and bankfull channel widths of nearly double as depicted in one of the graphs (Figure??), does this then trigger upslope analysis and is there a mechanism in place when you see these changes to alter, or restrain, management in other similar drainages so that same response does not occur?* At this point we have discussed this extensively, but have not set any thresholds to trigger management changes. I would hope that during this workshop we discuss what channel changes should trigger upslope monitoring and how to conduct these investigations. In regards to the specific changes in channel width between 1995 and 1996 we know they were caused during the large storm event that winter. We visibly noticed the results immediately after the storm when the flows had subsided, the alders were blown-out in places and the channel widened. Was this a "normal" response to the largest storm event since 1974, or was it more? I don't know. Comment by Trush: At the start of the monitoring project, we also looked at filled-in side channels and ages of specific stands of alders which indicated that since the 1964 flood, the channel width has decreased by maybe 300% to 400%. These analyses helped put the current channel condition in context with its recent (past 30 to 50 years) past condition. For example, the channel reach of discussion had an increase in channel width of 75% after a storm with a 15-year recurrence interval, yet since 1964 there was a decrease of nearly 400%. *Editor's Note:* The FFFC's long-term channel monitoring protocol also describes how to use series of historical aerial photos to interpret past channel condition.

A Brief Overview of Channel Monitoring in Land Management: Five Case Studies

Case Study #1: Presented by Leslie Reid, USFS, Redwood Sciences Laboratory

Yesterday we heard about some successful monitoring programs, but today I would like to share some findings from a study I did, which was basically a post-mortem of failed monitoring programs. There were about 30 projects, and I wanted to know why did they fail, and were there patterns of why they failed. The projects ranged from university studies, land management, and research. Costs ranged from $10,000 to $100,000.

Problems fell into two general categories:

1. Project design: problems that occurred prior to implementation, occurred in about 70% of the programs investigated.

2. Procedure: problems that occurred only during implementation, occurred in about 50% of the programs investigated.

Most of the programs had multiple problems, often in both the design and implementation phases.

Problems Identification:

1. Procedural: 37% of the projects, field staff was less than ideal. Possibly from inadequate training, education or motivation to follow procedure and accurately collect the required data. Lack of involvement by principle investigator to ensure collection of quality data.

2. Design: about 30% of the projects, monitoring methods used couldn't measure the variable of interest and answer the questions that the study was supposed to address. Example: a project to monitor the effects of suspended sediment from a logging road positioned samplers in locations that failed to detect the suspended sediment contribution of the road in the mainstem river channel.

3. Procedural: 27% of the projects, data analyzed too late to address the problem. Start working up and examining the data immediately and it may save future problems, such as the continuation of an incorrect field procedure. Example: a project where the data was not examined for 14 years from a project where a settling basin was used to catch sediment. What was the sediment yield from these basins? Unfortunately, the catches were surveyed after the sediment was dug out, so that every year the empty catch was surveyed – no change. The amount of sediment was never quantified. If the data had been examined after the second year, the procedural error may have been caught and corrected.

4. Design: 27% of the projects, study period was too short to detect changes or responses (especially if weather driven). Example: any five-year study during the recent (late 1980s)

California drought would not have shown much response to hydrologic events. Relates back to lag time between hillslope activity and channel response.
In defense of turbidity sampling, this parameter does have a quick response time and is probably one of the better "real-time" monitoring variables we have available. Turbidity monitoring is important especially if you are interested in the effects of what is currently happening uplsope. For example, in Humboldt Bay, a local watershed group monitored suspended sediment by sampling 11 days over two months at 14 locations (seven control locations and seven with varying degrees of landuse). Results: the turbidity rating curve was highly correlated to intensity of logging and road density upslope. Was in violation of the basin plan. About a 500% increase in turbidity in heavily managed watersheds.

5. Procedural: 20% of the projects, collateral information necessary to interpret results was missing. Example: using mixed units or no units at all for important measurements.

6. Procedural: 17% of the projects, the use of cryptic technology that fails when needed. For example, data files that are damaged, but are used because people assume they are correct. These data sets may be used extensively, providing mis-information for many years.

7. Design: 17% of the projects, inadequate problem analysis. Not enough evaluation of how to answer the questions regarding a specific problem or objective. Example: doomed reservoir, how long until the reservoir would fill with sediment was estimated by using the universal soil loss equation (only surface erosion) didn't consider landslide contribution (which was a dominant process) in the specific watershed. The reservoir had a calculated lifespan of 100 years, yet it filled in several years. If the planners had looked at aerial photos they would have recognized that landslides, not surface erosion, were the main sources of inchannel sediments and not have made the same calculation (or even selected a different dam location).

8. Design: 13% of the projects, basic misunderstanding of the processes, species, or parameters of interest. Example: population response lags, or need to understand the mechanism to interpret the results – there is a learning curve involved. The FFFC channel monitoring protocol may have to be implemented over long time periods before the links between landuse practices and channel responses are understood. Natural variation in channel form due to natural processes must also be teased-out over long time periods.

   In many cases on the current landscape of the Pacific northwest, assessment may be a more effective tool than monitoring for evaluating the effects of landuse practices because the experiment has already occurred. Monitoring implies that management will also occur in the future; whereas assessment can examine the current condition of the landscape and the past management practices that have occurred in the watershed.

9. Design: 13% of the projects, weak statistical design. Example: same statistical power could have been achieved with one-third the sampling effort. Can also prove any change is insignificant with processes with large inherent variation.

10. Procedural: 13% of the projects, personnel changes. Example: large turn-over of field crew, especially in monitoring that occurs over many years. Quality of the field work may vary from year to year.

11. Procedural 10% of the projects, lack of long-term institutional support. Example: lack of funding for long-term (decades or more) monitoring programs.

12. Procedural: 7% of the projects, change in protocol. Best summed-up yesterday by Trent McDonald, "protocol drift is not allowed."

Channel monitoring programs are particularly susceptible to several of those problems. Identification of trends and changes in channel form usually requires long monitoring periods because:

1. major changes tend to occur during infrequent storms so that many years may pass before change is provoked, and

2. gravel moves relatively slowly along channels so there is usually a lag between a triggering event and a downstream response.

It is difficult to use channel monitoring results to associate downstream responses with upstream activities because of these lag times, and because many factors influence the downstream response. These influences must be well understood so that relevant collateral information can be collected to allow interpretation of the observed.

It is important to define the objectives of a monitoring study carefully so that a strategy can be devised that will be capable of meeting those objectives. If the study is intended to provide feedback for adaptive management, for example, monitoring results must be available quickly and must relate directly to the outcome of the practices being evaluated. Once objectives are defined, methods other than monitoring are often found to be capable of providing the necessary information more efficiently. In many cases, the relevant "experiments" have already been carried out, and questions can be answered quickly by observing existing conditions rather than by monitoring future conditions.

Common Traits of the Failed Projects

1. Parameters were selected because there was an established protocol (but maybe not right for the specific watershed or objectives) or the parameters were easy to measure. Thus the program was not designed primarily to answer the specific questions posed.

2. Study plan was not adequately reviewed prior to implementation. Almost all of the 30 reviewed projects lacked adequate review of the methods to answer specific questions, or for statistical rigor.

3. Didn't understand the mechanism of the monitored response. This occurred both on temporal and spatial scales. Some studies may have expected answers (measurable responses) in five years, but in reality may not occur for 20 or more years of channel monitoring.

4. Principal investigator was not present in the field. In many cases having the person who designed the monitoring strategy in the field assisting in the data collection, and observing firsthand what is happening may alleviate some of the other problems encountered later.

5. Data analysis started after the monitoring ended. If data are entered and examined as collected, many problems with sampling design, protocol, or equipment failures can be detected and corrected early in a monitoring project.

6. Cost and effort were underestimated. Many studies failed to budget costs of data entry, analysis, interpretation, and report writing. All you end up with is a huge stack of data sheets buried in a file cabinet.

Remedies to these problems? Don't do them!

Current Channel Monitoring Protocol:

What is it designed to answer? Which of these two questions would you hope it could eventually answer?

1. How can the existing Forest practice Rules be modified over a five-year period to better protect public trust resources (salmonids, downstream water quality, etc.); or

2. How will the morphology of reach "X" of channel "Y" change over the next 20 years?

Hopefully the protocol is designed to address the first question. This is the preferred type of question that channel monitoring should try to answer.

Implications for Channel Monitoring Protocol:

1. Credibility: currently that both industry and regulatory agencies are perceived as lacking credibility with one another. The development of a channel monitoring tool that could provide information and quicker response to modify (improve) hillslope practices is a marvelous opportunity to gain scientific credibility.

2. Expectation: is that the channel monitoring will eventually be able to better address hillslope management practices and protect downstream beneficial uses. If the channel monitoring can meet these expectations, it would also provide industry a credibility boost.

3. Adequate funding: the proposed channel monitoring protocol is very expensive, costing Simpson three-person weeks to complete just the data collection in a single reach. There has

to be a long-term funding commitment to eventually get the answers to the specific questions and objectives. Additional funds are needed for other studies so that the channel monitoring does not occur in isolation of other physical and biological processes.

Case Study #2: Mary Ann Madej, U.S.Geological Survey Biological Resources Division

Over the years at Redwood National Park, the philosophy of the channel monitoring program in Redwood Creek has been, "Keep it simple." Because over the 20 years there have been numerous personnel changes, the methods used are relatively easy to implement and teach, are not too expensive, and are repeatable over many years with different field crews.

The program has detected change (or trends) in channel conditions, but has not always identified the causes of the detected changes. Long-term monitoring of cross sections in Redwood Creek (discussed earlier) has revealed trends in aggradation and degradation in different parts of the channel. Results have shown that areas that had aggraded after the 1975 flood subsequently underwent degradation. This mass of sediment moved downstream and caused aggradation downstream that was detected several years later.

However, today's discussion will not focus on cross sections, but instead on other aspects of the monitoring program on Redwood Creek. While you can not always determine the cause of a channel response without looking upslope, most people have an inherent interest in the stream channel. We have established some trend information for several parameters that may be indicative of stream health, however that may be defined.

Thalweg Profiles

Thalweg profiles are relatively easy to measure, use standard surveying equipment, are repeatable over time by different crews and inexpensive to implement. One needs to know the size of the feature of interest prior to sampling, so that the measurement scale is adequate to detect changes in that feature. If the feature of interest is a pool, then you need to take enough measurements within the pool to accurately define the pool, and to redefine the pool when you remeasure it to detect change through time. For example, if the feature of interest is a plunge pool consisting of a 1 ft. diameter sill log and a 3 ft. long pool, measurements need to be spaced closely enough to define that morphology. In contrast, such close spacing is not needed to adequately define long, uniform runs or glides in the channel.

Figure 1: Residual Water Depths

Figure 1 shows a distribution of residual water depths plotted against channel distance for a given reach. The mean, median, standard deviation, or other summary statistics can be calculated from the distribution of residual water depths. One needs to consider, however, when a non-statistically significant change is a biological significant change, or vice versa? Changes may occur to the channel that have no statistical meaning, yet have profound effects on aquatic biota (or the opposite may occur).

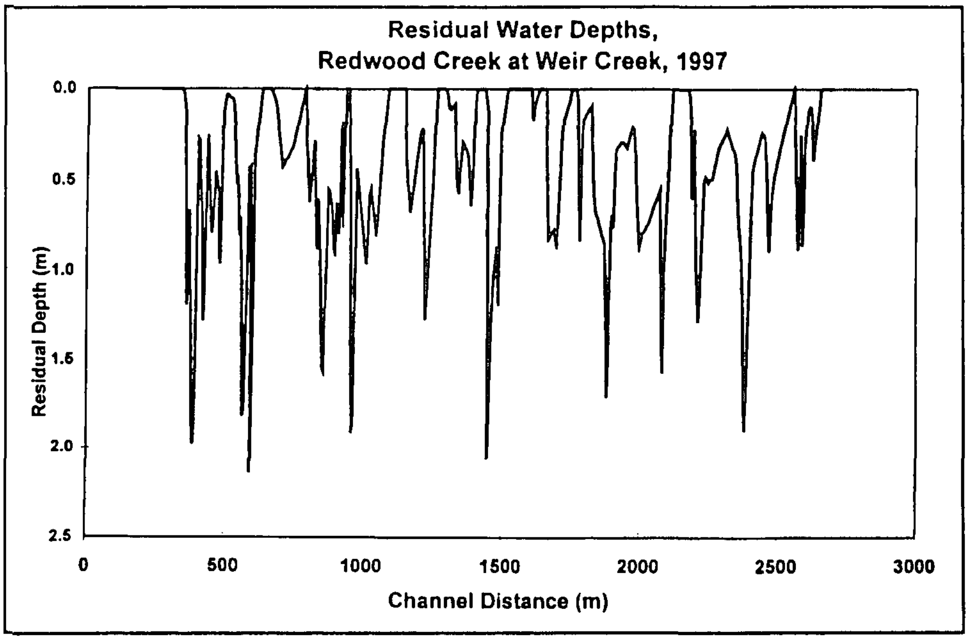


Figure 1. Residual water depths from the study reach Redwood Creek at Weir Creek, 1997.

Percent Length of Channel in Riffles

The locations where the residual water depth along the longitudinal profile is zero define the riffle sections of the channel. The length of habitat in riffles increased dramatically after the 1975 flood (Redwood Creek looked like a "pool table") and then decreased over time. Following the 1997 storm the percent of channel length in riffles again increased. Although the decrease in riffles after the 1975 flood was statistically significant, the biological significance of this change has not been quantified.

Change in Mean Residual Pool Depths:

Mean residual water depths increased the 1975 flood until the storm of January, 1997, when pools again filled with sediment. The variation in residual depths followed the same pattern as mean residual depths, in that the variation increased with time until the 1997 flood, at which time the variation again decreased. Variation in thalweg profiles was defined as the standard deviation of the distribution of residual water depths.

Variation Index of Thalweg Profile:

In order to compare variation over time from stream channels of different sizes, you must account for the size differences by standardizing the data. The variation can be either normalized by channel width or bankfull depth.

Standard deviation ÷ Bankfull depth = variation index

The variation index from several streams in the Redwood Creek basin increased after the 1975 flood, and decreased following the 1997 storm event. Higher indices were typical of streams classified as having better salmonid habitat.

Figure 2: Auto-correlation of Depth Measurements

Yesterday, Trent McDonald explained the concept of spatial auto-correlation. For example, if you take a measurement on a riffle, the neighboring measurements (if taken closely) will likely be on the same riffle (and similar in elevation). Auto-correlation should not be viewed as a problem, but more as a point of interest (what is the scale of correlation under different conditions?), and may itself be treated as a variable. It is useful to know the scale of autocorrelation when establishing sampling protocol. There are different coefficients available to define autocorrelation. I used the Moran's "I" coefficient to test for the scale of auto-correlation of thalweg measurements. When the "I" is close to 1.0, then the points are closely related (riffle-riffle, for example). If the "I" is close to negative 1.0, then the points are very, different from each other (i.e., pool-riffle)

In Redwood Creek at Bond Creek, for a channel length up to 46 meters the points were significantly correlated to one another (Moran's I was greater than 0.1). This represents the length of a riffle. At a lag distance of 400 m (representing points in the channel bed 400 m apart) there was another area of autocorrleation (Figure 2). An interesting point is that on some stream reaches you sometimes detect correlation again at these greater distances, which reflects a regular, repeating pattern of pools and riffles, commonly five to seven channel widths apart. At distances where Moran's I is less than –0.1 (i.e., 250 m in figure 2), the channel bed elevations are statistically different from one another, and represent the spacing between pools and riffles. The lag distance of significant correlation for different size stream channels was also examined. Auto-correlation is also a function of stream size: in smaller channels that lag distance is less than in larger channels. The scale of auto-correlation also changes through time: as the diversity of channel habitat increased, the lag distance of significant correlation decreased.

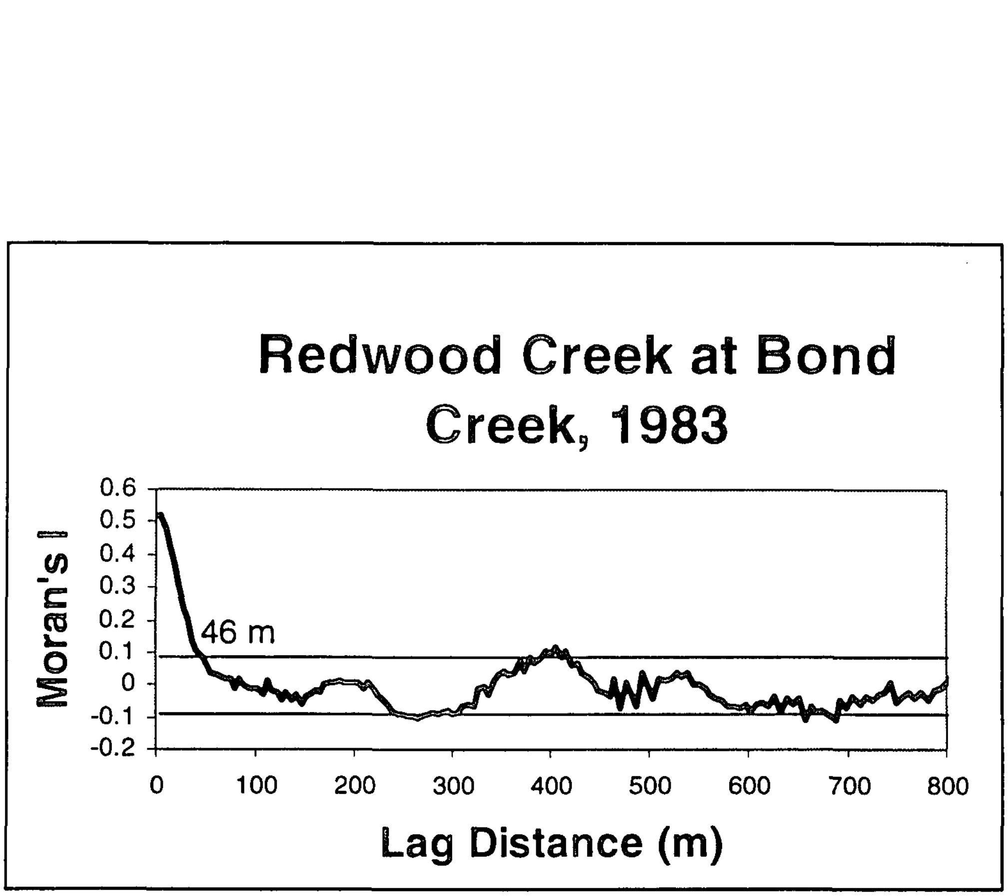


Figure 2. Auto correlation of residual water depth measurements along Redwood Creek near Bond Creek, 1983. Points >0.1 or < –0.1 are statistically significant in terms of spatial auto-correlation.

Effects of the 1997 Flood on Hillslopes:

We examined the hillslopes in the Redwood Creek basin after the January 1997 storm (highest peak discharge in 24 years). About 150 new or re-activated landslides entered directly into the Redwood Creek channel, and about 300 new or re-activated slides occurred in tributary basins. Most of these landslides were located in the upper basin, but they were distributed throughout the watershed. The widespread occurrence of landslides helps explains the filling of pools.

The next step is to ask "What caused these slides, and can they be prevented or reduced in the future by modifying land-use practices?" Ideally, it would have been better to have prevented the new landslides, but the fact is they have occurred. Now, we need to learn what caused the recent slides to prevent (or minimize) future incidences. We need to look at the hillslopes and ask "Did old landings fail, or did old sections of road blow-out?" Or did these slides result from failures of new roads, landings, and stream crossings, or where they due to legacy roads? What percent were natural failures that could not have been prevented

Channel Bed Particle Sizes

How much change should you expect in the system, and how sensitive is the measurement used to detect that change? Pebble counts are useful to characterize the channel bed in a general sense, but they are not sensitive enough to monitor changes in fine sediment in the channel. Pebble counts may help detect gross changes in surface particle sizes, but they are not suited for detecting subtle changes. There is high operator variability, and sampling protocol must be well defined. For example, in Redwood Creek two field crews conducted pebble counts at the same channel cross sections, but sampled a different length of channel bed. As a result, the median particle sizes (D50) measured by the two crews were very different.

Direct Sampling of Channel Bed Material

In a joint study, Tom Lisle, Sue Hilton and I intensively sampled surface and subsurface channel bed material in Redwood Creek. Samples were collected at several sites across the channel bed, and sediment was weighed and sieved. In the first sampling reach, 32 samples of bed material were taken from a localized area of the channel. Fines (defines as particles less than 1 mm in diameter) ranged from 6% to 54% of the total sample. In most samples the percentage of fines fell within a smaller range (12% to16% fines) (Figure 4) .

In the second sampling reach (Redwood Creek near Elam Creek), 50 samples were collected. Fines (less than 1 mm) ranged from 8% to 51% (Figure 5). The percentage of fines found in the channel bed varied widely within a short reach of stream. The Redwood Creek TMDL states that there should be no more than 14% fines (less than 1 mm) in the channel bed. Depending on what specific locations were sampled, Redwood Creek could be considered under or over the threshold of 14%, even within a single reach. Due to the large range of variability in percent fines, it will be difficult to evaluate the effects of land management by using trends of fine sediment.

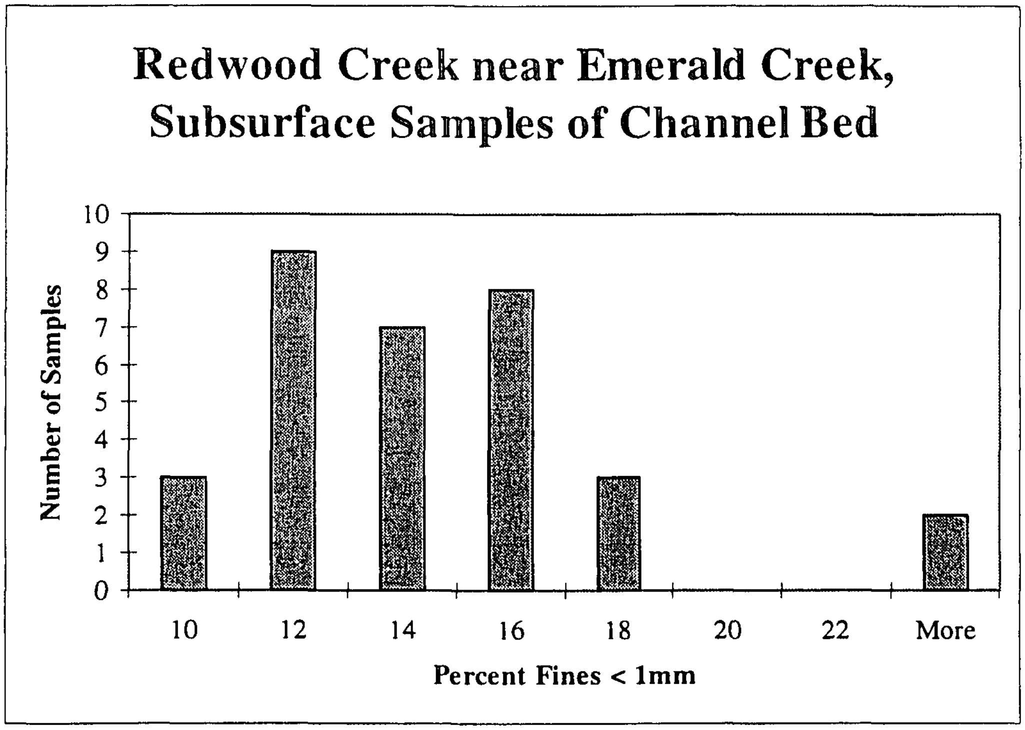


Figure 4. Percent fines of sub-surface particles measured in Redwood Creek near Emerald Creek.

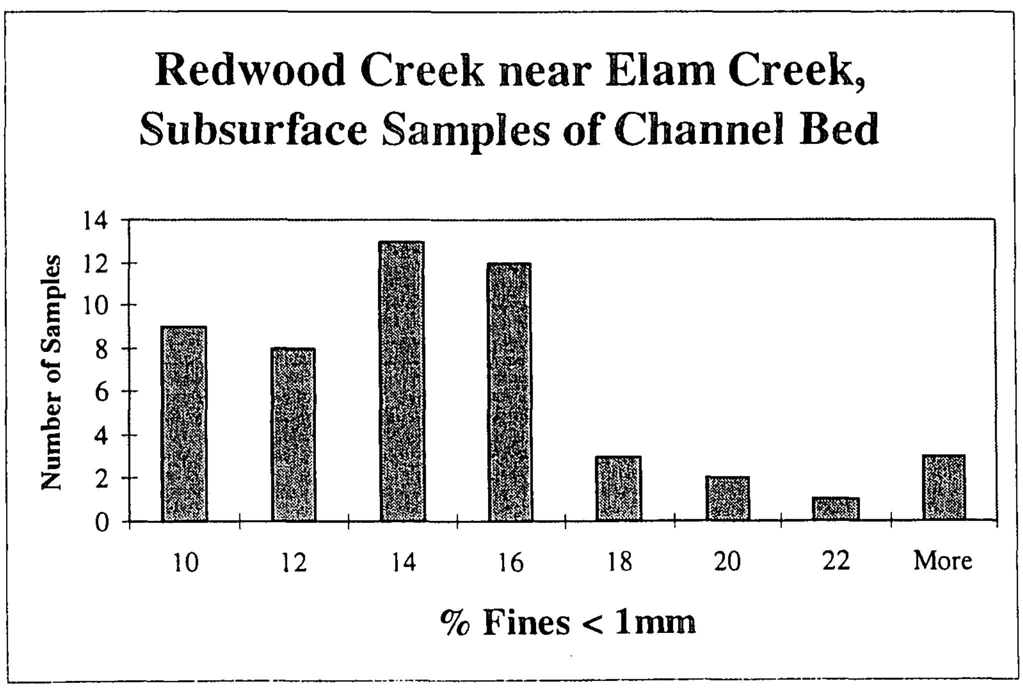


Figure 5. Percent fines of sub-surface particles measured in Redwood Creek near Elam Creek.

Channel Roughness

If particle size increases and bed morphology becomes more variable, channel roughness should increase. Manning's "n", a measure of roughness, was calculated for 20 years of discharge measurements in Redwood Creek. Manning's "n" decreases with increasing discharge as roughness elements are "drowned out." If the variability of roughness due to discharge is removed, we see an increase in roughness in Redwood Creek through time, from 1975 to 1996.

Suspended Sediment

There is a good relationship between the suspended sediment load and discharge for the period from 1972 to 1997. This relationship is called the suspended sediment rating curve. The rating curves are different in the early part of the study compared to more recent years. The slope of the curve (rate of suspended sediment transport increase with increasing discharge) was the same for the two time periods. However, the y-intercept shifted downward (fewer fines were transported at a given discharge in the later period, 1978-97). The flood of 1997 resulted in another shift of rating curve, and for a given discharge suspended sediment loads were again high. This increase was detected in both the 1997 and 1998 data sets. These data show the quick response time of suspended sediment generation. Within a few storm cycles increases in transport rates were detected. To detect problems with land management activities, it is important to monitor variables with a minimal lag in response time, such as turbidity or suspended sediment.

Closing Comments

Land managers are often frustrated when trying to establish reasonable monitoring protocols. They ask, "What should we monitor?" and "Why are you throwing out all these parameters as being too variable or having too great of lag-time?" We need to establish the balance of what we can actually detect through channel monitoring and what is useful for TMDL's, adaptive management, or other management activities. There is an inherent interest in the stream channel and the need to monitor changes in trends is important in understanding fluvial processes. Yet at the same time there are regulations on the books (regarding parameters of specific variables) which land managers and regulators must follow. We lack undisturbed, control basins in which to conduct long-term monitoring. Control streams are important in teasing out the natural variability of channel responses to floods and other natural disturbances.

Clarification Questions:

1. *One of the graphs showed the ability of the Redwood Creek channel to recover over time from presumably the impacts of past land management. Have you monitored channel conditions in sub-basins where management has been curtailed and road removal has occurred and compared these to sub-basins that are still actively managed for timber production?* Yes, but we have had limited success. We've monitored channel conditions in

Bridge Creek for the past 20 years. In this basin extensive removal of old roads, landings, and stream crossings was expected to result in channel improvements. Channel conditions did improve from 1984 to 1996. Unfortunately, when the 1997 storm hit, untreated sections of road in Bridge Creek failed. These road failures became huge debris torrents, which totally impacted the channel. The statement that road restoration in the watershed is reflected in improved stream channel conditions must be modified to include the effects of erosion from untreated roads in these basins.

2. *There is lots of information regarding the response of the Redwood Creek channel to the 1997 flood,. Do you have any information about changes in channel width after the flood event? Do you have any sense of the amount of sediment remoblized from terraces and gravel bars after that event?* We saw very little bank erosion at the monitoring locations and measured little change in channel widths due to the 1997 flood. This could be because past bank erosion had already widened the channel considerably, and the 1997 flood was not unusually large (a 12-year return period in Redwood Creek). One reach that did have a large amount of bank erosion had large volumes of deposits from floods in the 1970's. Here the stream has continued to erode into those deposits, causing an increase in channel width and remobilization of stored sediments. Overall, the magnitude of response in Redwood Creek due to the 1997 was less than that measured after the 1975 flood (a 25-year return period flood).

Case Study #3: Putting Channel Monitoring in Context. Mike Furniss, USDA Forest Service, Six Rivers National Forest, Eureka, CA.

These are the confessions of an empty-handed watershed monitorer who made many of the mistakes pointed out by Leslie Reid. I wonder how many others of you were squirming as she went through her list? I've done lots of monitoring over the years, and most of it hasn't made much of a difference to anything. I didn't bring any information to the land managers and policy makers I worked for to tell them anything specific about what they were doing was right or wrong.

The objective of my presentation is to put channel monitoring in the context of the overall monitoring imperative, especially from the viewpoint of a discharger (anyone how disturbs the watershed). Much of what I will discuss is my opinion that has crystallized from the time I spent as a member of the Northwest Forest Plan Effectiveness Monitoring team. When we opened up the topic of what should monitor in northwest Pacific aquatic ecosystems and watershed processes, it was very difficult and led to many hours of wonderful discussion. One of the products of serving on the Northwest Forest Plan team is a draft paper (available today) written by Leslie Reed and myself, some of which is very relevant to this two-day workshop. If some of what I say today pisses you off, please read the paper because it develops on much of what I will briefly discuss.

Currently there are more than 500 aquatic species were listed under the ESA in the past 25 years, yet none have been de-listed. What does this say about our ability to manage the health of the aquatic ecosystem? However, recently there has been a shift towards utilizing biological advice from scientists and technical experts to drive policy decisions. We have been given a much larger role in policy, it is our turn to bat, we must really set up to the plate. Do not blow this chance to affect the management of our natural resources.

I am some what alarmed by a trend I see, it appears that the interpretation of the primary monitoring task is to monitoring the long-term trend in selective parameters in high-order stream channels. Such as the Simpson monitoring program (which I commend the tremendous effort they have put forth) and some of the parameters addressed in the TMDL process as measures of success. Potentially a very broad deployment of this type of monitoring (priorities) throughout the Pacific northwest could occur. If this happens, in my opinion, it is a large mistake (on the order of LWD removal in the 1970's for fish passage – when too much was removed). We may look back in 10 or 20 years at our current channel monitoring strategies, and wonder what were we thinking.

However, there is still plenty of time, this is a draft protocol and we need to look at the overall monitoring situation. The FFFC Technical Committee should look at what gets monitored, not just the "how to" monitor. The questions of gets monitored is very important and difficult to decide.

There are some severe limitations to this type of monitoring that must be considered before relying on it as the primary method of choice. Uncertainties of the outcomes is a component of all management activities, understanding these factors requires a systematic procedure for learning from experience. The progress of understanding watershed processes would occur faster if learning was included as a valued objective of management actions, including long-term monitoring programs. So everything is an experiment, and then from the results use the understanding gained to truly adapt future management. This is the heart of an adaptive management concept, or in lay terms "learning from experience".

Who is the Client?

One of the first questions is, "who is the client?" What decisions that should, will, or must be made will be informed from the information we expect to collect? If you start with the decisions that must be informed and work backwards you may arrive at a different answer than if you do not start this way.

Likelihood of Useful Results

What is the likelihood that the monitoring will produce useful results? We need to define "useful" in the context of both the monitoring objectives and taking a very hard look at how likely will you produce results that are useful in adapting land management strategies.

Before making broad generalizations about the overall context of monitoring I must make several disclaimers:

1. There are plenty of situations where channel monitoring is appropriate and the best choice, such as large-scale diversions or removal of log jams.

2. We are lucky to live in an area with locals who are world-class experts in fluvial geomorphology conducting research on our area's watersheds. I am much informed by their work and there is a strong need for basic research in watershed and channel processes.

3. Monitoring stream channels is also extremely important for assessment.

Important Role of Basic Research

When the objectives are to monitor the changes of certain watershed products or pollutants as a byproduct from management practices as they relate to the health of coho salmon or steelhead, I have arrived at the following conclusion: Monitoring channel change in high-order stream channels is a relatively low priority. This type of monitoring does not contribute to adaptive management, at least not much. The best strategy is to watch the process drivers and the performance of specific disturbances.

Prioritization

This is often the dilemma we face: it is easy to come up with all things we could monitor, with some thinking and effort we can arrive at what we should monitor, but the most difficult is when we face the reality of budget and time constraints, as well as other factors is what can we monitor? There is a very wide range of *could*, *should*, and *can* as far as what to monitor. Must focus objectives on what is feasible and what will provide answers to the posed questions/objectives.

What makes for a Good Indicator?

1. Must respond quickly to provide results in the desired time frame. Many of the previous presentations have described the lag time between hillslope process and channel response, especially if you're monitoring the channel 40,000 to 80,000 feet downstream of the hillslope activity. It is too late for adaptive management to respond to changes detected in high-order channels. At that point you're just counting bodies, instead of managing by using preventative methods and strategies.

2. Cause-effect relationship that controls the indicator response must be well enough understood so you can arrive at valid interpretations. To learn from experience requires that we are able to infer causes from the changes detected. Is not possible if an indicator responds the same way to multiple stressors.

3. Changes must be interpretable in terms of the objectives of the monitoring program. Fish are adapted to a wide range of conditions and changes. Biodiversity is developed and sustained by geodiversity.

4. Signal (management-induced response) must be statistically separable from the "noise" of the inherent, natural variability. Dramatic change occurs to channels after floods – how do you separate the "natural" change from the "management-induced"? Or more specifically, how do you separate the current human influences from past human activities?

5. Measurement must be cost-effective at the required level of precision and accuracy. Long-term channel monitoring is expensive.

Currently, there appears to be a tremendous focus of effort towards channel monitoring. However, other areas of the watershed should also be considered such as road performance and stability in small tributaries, or landslide inventory procedures.

Monitoring the wrong parameters is not necessarily benign. Monitoring is failure detection, find the problems, correct them, and minimize future reoccurrence.

Watershed Management Assumption

If the natural processes (that deliver and transport watershed products) are intact, then the channels should be O.K. and take care of themselves. Changes will occur naturally, but the channels will rebound and at any one time channels may be in any state of flux.

When processes are thrown out of whack, the assumption is that the channels will suffer. Need to test this with research-grade validation monitoring (such as in Caspar Creek).

Should monitor the driving variables, not the response variables. These most often occur in the upper channel networks within watersheds (sometimes called the hillslope).

List of Favorite Indicators:

1. Thorough accounting of the stressors. Have to know what the experiment was (what were/are the past and current management activities). This is often lacking. Should look at the hillslopes concurrently with the long-term channel monitoring, and not wait until the threshold response in the lower channel variable triggers "a look upslope".

2. Onsite performance of forest practices, such as evaluating BMP's immediately after their implementation in the field. This type of effectiveness monitoring provides rapid, useful information for adaptive management purposes.

3. Amount of hydrologically connected road.

4. Stream crossing hazard rating. Measure the fill volume and diversion potential at all stream crossings within road network.

5. Landslide occurrence following large storm events.

6. Vegetation composition within two site-tree heights of all stream channels.

7. Turbidity and suspended sediment.

Case Study #4: Can the Federal and State water resource regulatory agencies make better use of measures of in-channel condition measures? Stephen Ralph, EPA Region 10, Seattle Washington.

The federal and state regulatory agencies need a reliable measure of how well land management regulations protect public water resources (e.g. water quality, resource integrity, salmon and trout) from non-point sources of pollution. {Pollution in this sense often refers to accelerated inputs of sediment, water and nutrients into stream, rivers and lakes. These changes reflect imbalances imposed by a variety of factors on the primary watershed processes that affect instream channel characteristics and aquatic habitats}. The not so distant past and present arrangement for regulation of land use related non-point sources of pollution is described. Based on the growing number of listed salmon stocks and waters that exceed water quality criteria, these efforts to date, have not been a resounding success.

A "one-size fits all" approach based solely on best management practices (i.e. prescriptions) for minimizing land use activities – unless extremely conservative - will likely continue to perform poorly in terms of meeting expectations for protection and recovery of public resources (e.g. fish community habitat needs and water quality). This is due to differing responses in different landscapes, variable disturbance histories, and inconsistent application of best management practices. There is growing recognition that this narrow approach may also have little use in the context of ongoing discussion associated with water resource recovery plans, including Habitat Conservation Plans and Total Maximum Daily Load allocations, because it does not take advantage of linking input sources with measurable, in-channel features. The needs for relevant, timely information is essential for successful use of the highly promoted but seldom tested concept of adaptive management.

Measurable **resource objectives** to gauge the relative success of land management prescriptions, although laudable, have often been vaguely defined and or inappropriately applied. These include features that reflect cumulative effects such as simple counts of LWD or pool spacing, that allow little understanding as to ultimate vs. proximate causes of the conditions described.

Do relatively quantitative and repeatable measures of instream morphological features have a larger role to play in the regulatory arena? If so, can the federal and state water quality agencies embrace these tools appropriately into their traditionally inflexible regulatory scheme? If so, will the champions of public resource protection buy into it? An idealized approach that (1) looks at activities and outcomes of management activities, (2) links hill-slope, riparian and in-channel features, and (3) utilizes landscape stratification principles - is briefly described. No doubt, other models exist and are being tested. Recent experiences in applying these tools to resource recovery plans are testing the ability of the traditional regulatory approaches, and providing a proving ground for application of these new ideas to address water quality and in-stream habitat needs in Western watersheds. These approaches would be substantially improved if and when channel monitoring techniques can show reliable results that reflect cause and effect relationships of land management practices, document status and trends in instream conditions, and aid in understanding the biotic response.

I plan to review some of the fundamentals of the regulatory world and place them in context with some of the information that has already been presented. I will probably reinforce some of the recommendations already made for getting out of the channel and looking upslope as well when conducting monitoring. Regulation of land-use effects on aquatic resources – are we looking at the correct signals?

Current water quality standards: very few numeric criteria for parameters that are pertinent to salmonids. Mainly limited to water temperature and turbidity.

Traditional water quality regulations addressed non-point source (NPS) effects.

1. Prevention: often BMP's applied across the landscape in a blanket fashion without a systematic approach to evaluate their effectiveness.
2. Limited basis to judge acceptable (of the system potential)..
3. Recovery – TMDL's. The EPA is now a believer in this approach after losing 42 law suits. Difficult to construct and apply, in part, because of legal and legislative constants.
4. Cause versus effect – TMDL's have a limited ability to focus on this aspect.

Integrating Clean Water Act (CWA) and ESA Authorities:

What we're currently attempting to do in Washington is couple the language and intent of the CWA and the ESA, because both Acts require similar kinds of measures to judge recovery and success of various management strategies.

1. Coupling a habitat conservation plans (HCP) and TMDL's with a large private landowner (managed for commercial timber production).
2. Sharing task of defining the specific objective criteria to judge the plan's success.
3. Main benefit of this approach will hopefully be an efficiency of interpretation of the results from the monitoring and assessment conducted.

What Indicators to use to Judge Success:

This has been discussed and debated during most of the previous presentations. The continued reliance on just instream indicators is "the road to failure" because of the natural variability, potential measurement error, and difficulties of linking cause and effect. I argue we need a new approach especially when you consider where past landuse and monitoring has led us: thousands of water bodies listed as failing to meet minimum water quality standards and the ever-growing number of listed aquatic species.

Need a New Approach:

1. One that includes diligent assessment and appropriate monitoring.
2. Links hillslope and channel processes to variables we can measure and are also ecologically meaningful.
3. Directly measures the sources of watershed inputs and tracks actions and outcomes.

In this current HCP/TMDL strategy we want to focus on measuring the sources of inputs that affect both salmonid species and their habitats. These are the drivers of the expression of the instream channel conditions that fish usually relate to.

What should it include?

1. Logical stratification of the landscape to better understand the natural variation of conditions across the ownership and the expression of the "drivers" (input of water, sediment, LWD, heat).
2. Also put the expression of the drivers in context with the past logging and other land management activities.
3. A monitoring system for the long-term evaluation of the components because much of the change towards recovery in this managed watersheds will not occur in our lifetimes. At least in our ability to detect change and definitively link cause and effect relationships.

Evaluation Components:

1. Sediment input sources from roads, hillslopes, and bank erosion because these are the three primary ways sediment enters the channel. Targeting "X" percent reductions in first ten years of the plan on the areas identified as highly erosive.

2. Stream temperatures, specifically evaluating the effectiveness of the riparian management strategies tailored for the range of existing geomorphic conditions defined across the ownership. Based upon on the projections of the amount of effective shade provided by different riparian management strategies. Provides some fundamental assumptions to test and some specific target values to evaluate success.

Accounting System for the Plan:

1. Have an agreement with the landowner to set up an advisory group of scientists – company, agency and tribal biologists. The advisory group will serve as an in-house panel to review data as it is collected and to reconsider the appropriateness of the monitoring objectives. This is important because monitoring is an iterative process of successes and failures, and one must make adjustments accordingly. Need to analyze and review data constantly as it is collected.

2. Annual audits of sediment abatement actions: where, when, and what was it done across the landscape. Targeting highly erosive areas identified because of their geomorphic characteristics and potential for significant sediment contributions.

3. Look at inchannel conditions to track changes over time, but not given lots of weight in determining successes or failures.

4. Survey biota such as juvenile relative abundance or health/condition of out-migrating smolts.

Landscape Stratification Scheme:

The 217,000 acres of the ownership was divided by three levels of stratification:

1. Sub-divided into two sub-ecoregions regions defined by EPA.
2. Further sub-divided into five lithotopo units based on parent geology and topography..
3. Further divides the lithotopo units into 49 channel types based on gradient, parent geology and size.

Purpose of the Stratification Scheme:

1. Group channel segments by dominant hillslope and channel physical processes.
2. Assigns specific riparian strategies that reflect important riparian forest functions and interactions (in different settings).
3. Mapping of biological resource associations.
4. Allocation of assessment and monitoring.

Four Points Critical to Understanding Various Watershed Processes:

1. Productivity of the streams. This is the tie back to the biological components.

2. Their response to historical logging practices and natural disturbance events. This is naturally a very dynamic landscape and the watersheds are still responding to the effects of past logging, as well as current practices. Large disturbances are part of the natural processes of these watersheds and salmonids have evolved and adapted to these conditions over many, many millennium. However, the rate, pattern, distribution, and persistence of the events has been affected by landuse practices.

   The plan only holds the land managers responsible only for their contribution to the watershed impacts. This is the challenging part

3. Within the stratification scheme, we must attempt to understand the various habitat characteristics. Need to understand the inherent potential of the different habitats expressed across the landscape. They will not all be equally productive or perfect. It is the diversity of habitats that has allowed the salmonids to diversify into seven species and hundreds of distinct races or stocks. For example, in one river you may have five or more distinct life histories of chinook salmon.

4. Stratification scheme will assist in the understanding of the sensitivity to current and future logging practices within LTU's and channel types. Specifically a mechanism to test or challenge some of the assumptions about the efficacy of various riparian prescriptions and sediment abatement programs.

First Level of Stratification, Lithotopo units (LTU's):

1. Alpine Glacial (AGL) = 10% of land base.
2. Crescent Islands (CIS) = 14% of land base.
3. Crescent Uplands (CUP) = 11% of land base.
4. Recessional Outwash Plain (ROP) = 38% of land base.
5. Sedimentary Inner Gorge (SIG) = 27% of land base.

The main point I want to make is that it is very helpful to look at the different landforms and how they were created to better understand the drivers of watershed processes and hopefully apply management prescriptions accordingly. For example, in the ROP land is mostly flat and was formed by repeated glacial advance and retreat. There is little potential for hillslope failure and most sediment and LWD input is from local bank scour. This is very different than the (CUP) that is very steep and highly erosive that is prone to large hillslope failures that episodically deliver large amounts of sediment and wood to the channel. Obviously, you would prescribe different management prescriptions for both sediment abatement and LWD recruitment within these two LTU's.

Alpine Glacial (AGL):

1. Includes Wynoochee River and tributaries.
2. Glacial deposits of native gravels, sands, silts, and clays.
3. Some highly cemented and resistant to erosion
4. Sediments are delivered via bank erosion and shallow rapid landslides along ancient terraces.

Crescent Islands (CIS):

1. Basalt "islands" surrounded by low gradient, gravel rich stream systems.
2. Large deposits of unconsolidated sand and gravel form channel banks.
3. Excellent spawning for coho and chum salmon.
4. Susceptible to fine sediments via bank erosion.
5. LWD is recruited via bank erosion and channel migration.

Crescent Uplands (CUP):

1. Southern foothills of massive basalt and breccia rock types.
2. Sediment delivery is via debris flows from bedrock hollows, first order channels, and shallow rapid landslides.
3. Highly dissected landscape = high connectivity with road systems.
4. LWD input from catastrophic slope failures = large valley log jams.
5. Rain on snow events are common.

Recessional Outwash Plains (ROP):

1. Encompasses extensive area of low relief west of Shelton, WA.
2. Formed by repeated advances of continental ice sheets.
3. Soils rich in sediments foreign to the Olympics, some impermeable lens.
4. Channels are low gradient with abundant gravels in bed and bank materials.
5. Sediment and LWD input via localized bank erosion.

Sedimentary Inner Gorge (SIG):

1. Marine siltstones, sandstones, and mudstones are highly erodible.
2. Channel network is deeply incised.
3. LWD via sediment processes
4. Sediments are from:
   - Massive, deep seated landslides of many ages.
   - Inner gorge side slope failures
   - Shallow side slope failures in sandstones
   - Extremely high erosion rate for bedrock channels.

Second Tier of Stratification - Channels:

1. Based on channel width, confinement, and bed morphology.
2. 49 channel types identified.
3. Many occur in several LTU's, but differ in major physical channel processes and ecological roles (dynamics of LWD, water and sediment).

These 49 channel types and five lithotopo areas have been mapped-out across the 217,000 acres of the plan area into the company's GIS system. Company personnel have also ground-truthed the maps to validate the accuracy of the mapping exercise. For example, channel cross sections from the SIG and ROP lithotopo units are presented and show the different riparian prescriptions proposed (Figures 1 and 2).

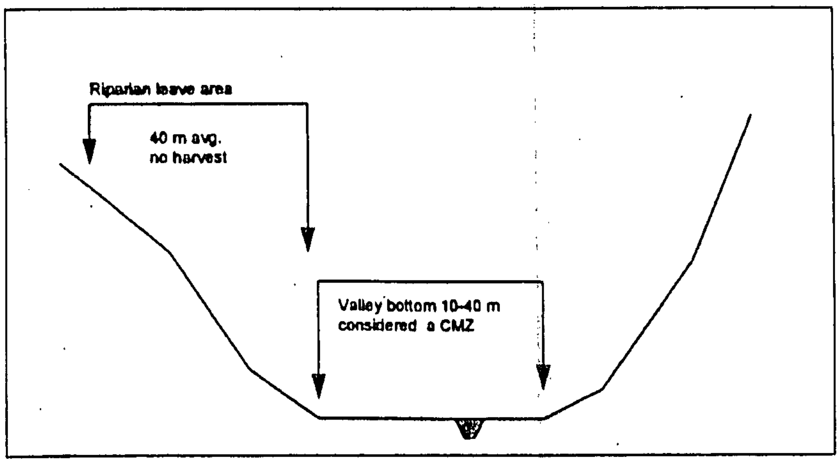


Figure 1. Valley cross section of typical SIG – L2 channel segment and proposed riparian leave area. In Cook Creek, this class provides important coho spawning habitat but in the Canyon River this class is blocked by waterfalls near their mouths.

Loading Capacities:

1. Temperature – as a function of <u>effective shade</u> afforded by riparian prescriptions and judged within their landscape context.

2. Sediment – as a function of hillslope <u>input sources,</u> road surface erosion and bank erosion and judged within their landscape context.

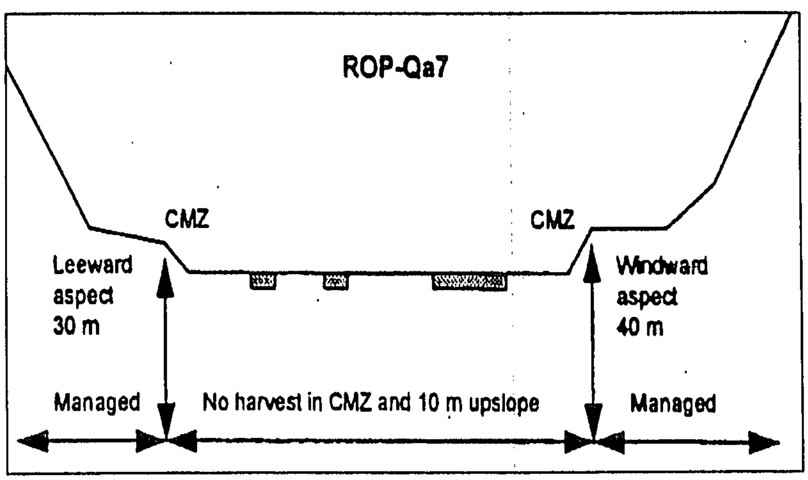


Figure 2. Valley cross section of typical ROP – Qa7 channel segment and proposed riparian leave strip. This class commonly has a braided channel pattern and occupies a rapidly changing channel migration zone.

Looks at Stream Temperature and Sediment as "other appropriate measures":

1. Stream temperature as a function of solar input – riparian shading and channel widening.
2. Tracks sediment "loading capacity" via input sources and routing to channels.

Temperature Allocation:

1. Evaluates level of shade afforded by specific riparian prescriptions applied to each channel type. (SHADOW model = effective shade targets).

2. For protection – height of riparian vegetation is estimated and evaluated through field measurements.

3. For recovery – projection of re-growth of riparian vegetation in areas already logged by past prescriptions.

4. Have recognized that different temperature "families" exist by LTU and controlling factors. Depending on LTU, temperature may be more influenced by shade, channel widening, sediment input, or groundwater.

The concept of the plan is to use the SHADOW model to predict the effective shade (as a %) that is needed to meet current water quality standards in Washington (16°C), apply management prescriptions to meet these targets, and use monitoring to validate the model predictions and management prescriptions. If we find a management approach doesn't work then we'll have some further discussions about the controlling mechanisms and ultimately about the characteristics of the riparian leave strip. This is where timely data entry, analyses, and interpretation is imperative.

Sediment Allocations:

1. Erosion processes are defined (hillslope, road, and bank sources) for each LTU).

2. LTU – basin sediment budget (background and induced) are estimated.

3. Reduction targets are set (50% reduction in the first 10 years). The reduction is not from "background levels", but from the rates inferred from thirty years of historical aerial photo analyses.

4. Estimates are calibrated by field work and ongoing monitoring.

I realize I went through a fairly complex management strategy quickly, but that is an overview of the approach being taken by a large timber company in Washington. Again, the important part of the plan is the stratification of the landscape by LTU and channel type, understanding the drivers of watershed processes, and prescribing riparian and sediment abatement strategies accordingly.

Clarification Questions:

1. *How did you arrive at the 30-year time period to estimate rates of erosion?* Basically this was the limit of the best series of historical photos available. The approach we're applying is an approach that the EPA has used constructing TMDL's in Idaho – a risk assessment model developed by Jim Fitzgerald. The process constructs a sediment budget for a whole watershed and looks at natural sources versus anthropogenic sources. As part of the model, one goes back and looks at historic aerial photos to reconstruct past sediment inputs by mapping-out where slides occurred and estimating volumes of sediment inputs. On this ownership watershed analysis has occurred in some of the basins and about 800 landslides have been mapped (mostly in the AGL and CUP lithotopo units). So we already a pretty good initial assumption about what streams seem to be contributing most of the sediment and by what mechanisms.

2. *What about the use of a reference watersheds of similar geologic and hydrologic characteristics to get at natural rates, it seems looking just at these managed watersheds for only 30 years all you're seeing is potentially excessive?* Yeah, that's a good point and I guess we have the Olympic National Park adjacent, but in reality we have very few other watersheds in this area that haven't yet been harvested. Many of these watersheds were subjected to the old log drives of the 1920's and 30's and a lot of the channels were just completely reamed. We have had some discussions with the Park Service along these lines to better understand natural rates of sediment and LWD inputs.

3. *Would you recommend developing LTU's here on the north coast (CA) for setting TMDL's?* (laughter from audience) You know I'm just sort of here to present our strategy with this company up north, I feel like the long-lost relative who shows up for Thanksgiving dinner with a carton of Camels and a bottle of Jack Daniel's. Seriously, there's still not consensus on our approach within EPA, some say, "it's too complex, lets have another meeting and contemplate our navels". I feel it's necessary to get organized and at least apply this logical approach, to see if it works, learn as we gather results, and modify management as needed. At least something can be applied and learned from our process and related to the north coast. I am surprised by the lack of discussion so far at this meeting trying to coarsely stratify the landscape so you knew the areas that have the greatest signature for sediment input and attacking those with upslope sediment abatements. ***(Editor's note:** for large ownerships such as Simpson's, the FFFC's protocol recommends locating long-term channel monitoring sites in various watersheds stratified by geologic and hydrologic characteristics).*

4. *Are the State regulatory people satisfied that the targets will be met by the existing rules or that the changes are warranted?* The proposed riparian strategies in the plan are a whole new ballgame, way beyond existing rules. For the most part in WA., most of the industry and regulatory folks agree that the existing rules (as applied in the past and currently) are not

going to get us towards where we want to be on temperature and sediment. In Oregon they still seem to have a different belief system (more laughter).

Case Study #5: Physical Habitat in Streams: What to include and how to interpret it. Philip R. Kaufmann, USEPA, Corvallis Oregon.

Effective environmental policy decisions require stream habitat information that is accurate, precise, relevant, and affordable. Decisions on what aspects of habitat to include in a monitoring program and how to measure them depend upon program objectives. Programs focused on direct evaluation of change in particular habitat attributes may include a more restricted array of measurements than those assessing habitat in a more holistic manner, or those using habitat information primarily as an aid to interpreting biological information. Similarly, programs focused on monitoring and interpreting habitat condition at a relatively few specific sites may spend more effort at each site than regionally-focused programs that require measurements at a large number of sites in order to make regional inferences. The U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) is a regionally-scaled effort designed to interpret regional patterns and trends in the ecological condition of surface waters, based on a wide spectrum of biological, chemical, and physical measurements and indicators measured on a statistically representative sample of stream reaches. The array of physical habitat information collected by EMAP field crews is intended to be sufficiently comprehensive to facilitate interpreting biotic data, when used in combination with water chemistry and landscape data. The program characterizes the major habitat features that may operate as controls or limiting factors on biotic assemblage composition under natural or anthropogenically disturbed circumstances. These include measurements and observations to quantify stream habitat space, stream gradient, substrate size, fish cover and habitat complexity, riparian vegetation cover and structure, riparian disturbances, and measures of the interaction between the stream and its floodplain.

The EMAP field approach samples many stream reaches throughout a landscape or basin. Field crews employ a randomized, systematic sampling design to specify the location of measurements and observations on each stream reach. The length of each sampling reach is defined proportional to stream width, with measurements systematically placed to represent the reach. The sample reach is a length of stream channel 40 times as long as its wetted channel width at the time of sampling.

The time commitment for collecting data at each sample reach using these methods is considerably less than typical of site-specific research programs. However, the EMAP field methods require more field effort than do more qualitative methods. In our field surveys, two people typically complete the specified channel, riparian, and discharge measurements required in the quantitative approach within 1.5 to 3 hours of field time. The quantitative methods also provide greater flexibility in interpretation and re-interpretation than do the qualitative habitat scoring approaches, because interpretations of habitat quality are made during data analysis, rather than during field data collection

We evaluated sampling precision of field habitat survey methods employed by the USEPA's EMAP in several hundred streams in Oregon and the Mid-Atlantic region. We compared variance among streams ("signal") with variance between repeat stream visits (measurement "noise"). Quantitative channel morphology and riparian canopy densiometer measurements were precise (signal:noise (S/N) ratios mostly 6:1 to 20:1) when applied to features that are clearly defined and not excessively sensitive to differences in flow stage. Flow-sensitivity (e.g. width, depth) and ambiguity in features to be measured (e.g. incision height) limited precision, but still resulted in metrics generally within the moderate to high precision range (S/N 2.0 to 15). Semi-quantitative measurements (e.g. substrate size metrics) and presence-absence determinations (e.g. visually estimates of canopy presence) were generally intermediate in precision between the two quantitative measurement groups (S/N 2.0 to 16), but included several integrated metrics with S/N >20 (e.g. mean substrate diameter). Visual estimates of riparian canopy cover tended to have low to moderate precision S/N <4.0, as did visual estimates of the areal cover of fish concealment features. Commonly used flow-sensitive measures (e.g. riffle/pool and width/depth ratios) and qualitative visual assessments (e.g. EPA's RBP habitat scores) tended to be imprecise (S/N <2).

Based on our results, we make the following generalizations concerning the precision of habitat measurement and assessment approaches:

- Measurements are more precise than visual estimates, but carefully-designed, repeated visual estimation procedures can be nearly as precise as measurements. In these cases visual estimates are made of measurable characteristics (e.g. cover or presence), not judgements of habitat quality.

- Flow-sensitivity and complex definitions of habitat features can degrade precision of quantitative measurements (e.g. bankfull height and incision).

- Flow-sensitivity and subjectivity in habitat-unit classifications (e.g. %Pool) can seriously limit their usefulness in contrasting stream habitat among streams or in tracking changes in habitat through time.

- The precision of multiple visual cover-class determinations can be improved by re-interpreting this information as extent of presence-absence of some defined feature (e.g. summed vegetation cover in two layers reinterpreted as percent of observations in which cover is >0% in both layers).

- The precision of separate metrics can be improved upon by combining them into more integrated metrics. (e.g., the precision of %Substrate <16mm diameter is more precise than separate metrics of %Fine Gravel, %Sand, and %Fines; the precision of %Pools+Glides is more precise than %Pools).

- While visual judgement methods are attractive because of their rapidity in the field and in data reduction, their lack of precision limits their use in many applications.

- At least 20 pairs of repeat field visit spread over several years are required for confident assessment of within-season precision in physical habitat metrics. These repeat samples are ideally drawn as a random or stratified random sub-sample from a regional probability sample of stream reaches.

- Metrics with S/N <2.0 may distort regional population distribution estimates based on survey results, and may severely limit analyses of associations by regression and correlation.

- The error in regional stream population distribution estimates due to field measurement variance and short-term temporal fluctuations is relatively insignificant when the signal-to-noise ratio of a metric is • 10.

- When metric S/N variance ratios are • 10 field measurement variance and short-term temporal fluctuations offer relatively insignificant obstacles to analysis of associations using regression and correlation.

Unfortunately, comprehensive, quantitative physical habitat field methods can produce a bewildering array of raw data. We reduce the complexity of this data by calculating metrics that summarize stream reach habitat characteristics, also making an assessment of the repeatability of these metrics. Going beyond simple descriptions, regional assessments usually require that we evaluate associations that implicate channel responses to basin-riparian disturbances, or biotic responses to habitat alteration. In large regions, human land use disturbances typically overlay wide ranges of natural geomorphic factors that control both habitat characteristics and biotic assemblages. I'll discuss a variety of approaches for estimating the degree to which streams deviate from "natural" or "reference" conditions, including use of historical information, best professional judgement, reference sites, impairment threshold criteria, and the use of process-based or empirical models to estimate reference condition. For example, many measures of stream "health" based on biotic assemblages (e.g. macroinvertebrates) show consistent association with habitat metrics such as substrate size, though substrate size is controlled by both natural and anthropogenic factors. Critical to assessing alterations in substrate size are stream gradient, size, and large scale roughness, which together determine the stream bottom shear stress. Uncorrected for natural gradients in shear stress, biotic assemblage metrics may show spurious relationship or lack of relationship with watershed disturbances. In a related example, we examine the relationships between land use and stream substrate by estimating substrate stability during bankfull streamflows, adjusting for energy losses from large scale roughness. Observed stream substrates substantially finer than those predicted by this model suggest that sediment supplies are large in relation to a stream's ability to move sediments, leading to bottom textural fining or sedimentation. In our data, sediment textural "fining" is associated with basin and riparian land disturbances, suggesting that bedload sediment supply is generally augmented by human land uses.

Panel Discussion

Editor's Note: The following text was transcrbied directly from audio tapes recorded during the workshop. Some editing of extraneous conversation was deleted, however the remaining text retains the "flavor" of "spur-of-the–monent" answers to some complex and diffiuclt questions.

Moderator: Question for Lowell Diller.

One of the stated objectives of Simpson's channel monitoring program is to determine the affects of land use, do you believe the monitoring will or can achieve this objective?

Lowell Diller: Well, basically, for clarification I don't think I actually said that. I am glad this question came up to help clarify things, this workshop is not about assessing Simpson's monitoring program, and if it was I would have given the full monitoring program which in fact includes headwaters components. I am going to review this now because a lot of people seem to think that is what this is about. Our monitoring also includes the following components:

1. We are looking at headwater streams where we have treatment of controlled areas in headwaters where we are looking at the impacts of harvesting on several biological indicators. We have before and after treatment and control sites regarding temperature monitoring in headwater streams, in fact there is a whole lot of temperature monitoring going on (fish-bearing reaches too).

2. We are looking at fish populations and comparing survival rates between summer counts of young-of-the-year and out-migrant counts conducting the following spring. That is, to compare populations in the summer to out-migrant trapping.

3. We are starting to do road assessment work, to look at the conditions of roads, stream crossings, and landings.

So there are a whole bunch of things in the process of development and the channel monitoring is just one part of that entire program. We never thought that with channel monitoring alone we would be able to determine what the impacts of our activities are on all these watershed processes. This is just one small part of it and that is why in my opinion we want to keep it very focused on just simply looking at the change over time of these channels and with the evidence, we hope to be able to detect what is happening in the watershed, so I hope this is a clarification.

Also, this is all in the development stage, we haven't implemented any of this from the standpoint of a full blown monitoring program, the channel monitoring stuff we are right now still testing the protocols, you saw that we are still changing them. We just looked at the data for the first time two days ago, and people were saying "Why didn't you respond to some of this stuff?" Managers at Simpson simply haven't seem this data yet. I've just seem it myself and I don't even know how to respond to it, much less taking it to management. So the point is this is all part of the development of a monitoring strategy that is supposed to be part ultimately of a habitat conservation plan and all of this at some point will fit together.

At this point it isn't complete but we are trying to develop up some protocols here. So this workshop is about assessing these draft protocols. Leslie is disappointed in the objectives. They thought we were going to solve all the world's problems here with this one protocol and in my opinion we are just looking at this one particular protocol and looking in the context of all the things that are available. Another thing I want to point out, this is about the FFFC's effort not Simpson's effort and the protocols we are developing We are trying to look at a whole suite of things and look at those in terms of putting those in the context of an overall monitoring program so I think part of the problem here is that people have had different ideas about the objectives of this workshop so I don't know if I answered your questions but at least I got a few things off my mind.

Prior to working for Simpson, I was an academic for almost ten years, and I was like Bill Trush, I could walk in front of students, wave my arms and so forth and they would believe this stuff, because I was in a position of authority and assumed I knew what I was talking about. Students would believe everything I said and at times I would caution them , "Don't believe this just because you heard if from me", and at times I would intentionally tell them bullshit to see if they would catch it and they wouldn't. I went from that situation in academics where everyone believes what you say to working for a timber company where no one believes what you say and you had to prove everything.

I wanted to stress that this protocol has to be something that has no subjectivity to it or very minimal. The methods have to be something you can agree on in advance, including how are you going to analyze it and how are you going to interpret the results. When you work for the timber industry that is a major consideration that we are not researchers and we are not viewed as being objective and unbiased so the protocol we develop has to be very rigid so that the methods can be scrutinized in a way that everybody will accept the data.

Bill Trush - I think what Mike Furniss brought up today about the steps leading up to deciding these protocols that may be where people perceive the timber industry will input the most bias rather than developing a thalweg profile everyone agrees to, or measuring temperature. It is more getting to the study design, questions, expectations, folks might feel that is where the real bias is coming in, but that is not really a subject of this workshop. But is it of the FFFC as a whole, I'm asking, is that - you know getting up to deciding on how to do a thalweg profile that's a huge jump to that point, the study design in question, Is that going to be addressed by the FFFC?

Lowell Diller - I thought that is what this conference is about.

Bill Trush- It seems more on the methods rather than on the study design and questions being asked. I think Mike brought that up today.

Lowell Diller- Is Tommy Williams here, he mentioned a quote from Jurassic Park just before we came in here, regarding chaos theory? "We never stopped to ask whether we should be doing this, we were so concerned with whether we could do it?" And I think it would be valuable and it's hard but I don't see how you can avoid this step, of backing up and saying, "OK what suite of monitoring methods, parameters, and strategies are most appropriate?" We need develop priorities for various kinds of areas, that would be a most interesting two day workshop, and the methodological stuff is probably less important to collaborate over than the, "what should we be doing, not how we do it".

Phil Kaufmann - As much a question as a comment - It seems also that the site-specific focus of the TMDL process is leading folks like Simpson to nail down precision at a site or perhaps at the basin level, at the expense of nailing down the holistic picture at the regional or the coast-wide. You're being forced, as you said, to have something to stand up in court at a site, where we may be losing the forest for the trees by not having something that stands, at least that tells us a story over a region-wide level.

Moderator - I think for the FFFC Policy Committee, we look to our Technical Committee to explore that question – " what suite of protocols is needed what needs to be sampled, at what levels and what's it going to tell us". What I have heard in the last few days is we need more help with that.

Moderator: Question addressed to everyone on the panel.

Should anyone monitor stream morphology? Some people seem to say yes, some say no, has the decision been made? If not I think it should be made.

Leslie Reid - I'll start in, I think it is absolutely essential to monitor stream morphology to answer specific kinds of questions in specific contexts. Some of the work that Tom Lisle is doing, when it is in a research context to understand how the channel processes work becomes extraordinarily interesting. Some of the work he is doing looking at how sediment from a landslide is transported through a drainage basin by looking at sequential changes in channel morphology that's beautiful stuff. Stuff that could then become, when we get to the point where we start to understand how that works, that is the sort of information that can be applied to much wider areas to many other different kinds of contexts to allow us to understand general patterns of change in a lot of other places.

The kind of things that Redwood National Park is doing, the long-term monitoring of Redwood Creek has allowed us to understand a lot about how these channels process sediment and that information can then be used in New Zealand, for example, to understand how channels are likely to respond. So a few of these studies that are really serious long-term commitments or studies that maybe are short -term commitments but done under a very rigid study plan for a very specific purpose are absolutely essential to bettering our understanding of how these systems work.

Randy Klein - Well, I think it is important for some other reasons too. If we are ever going to get towards identifying thresholds of disturbance over relevant managing areas, we need to know what sort of source inputs we can generate before we start to create morphologic problems in streams.

Mike Furniss - Also, I don't hear anyone talking about predicting recovery rates and the long-term monitoring is at least getting a handle on where things are going. Obviously I support, I recommended doing it. When we did the first year we surveyed off of the main channel we found that probably the bankfull was about 300% wider than it is today. It has changed a lot, there's been a tremendous fluvial adjustment just in the last 15 years. We've been hearing you're not going to see change for hundreds of years, there is plenty of change you can see, I can show you all over the South Fork Eel there's been major changes in channel morphology from the tractor logging in the '60's where it was pretty much left, the roads were melting but I still see some major geomorphic adjustments towards channel narrowing. No one is really predicting what the recovery rate is going to be. And I think we have to stay on top of what is happening in these rivers. So I don't think of channel monitoring simple as research, where Leslie is inclined, but more long-term monitoring for the sake of general channel response, I see it as important.

Randy Klein - I can add to that, and make the analogy that long-term channel monitoring at consistent sites and by consistent methods is analogous to the USGS stream gauging program. The stream gauging was started nearly a century ago with no explicit hypothesis testing stated up front but has been used in hindsight to answer lots of cause and affect type questions, it's a sort of ambient baseline fundamental monitoring program that has gone on and served us well.

Mary Ann Madej - Decades ago there was a proposal for a digital network in making long-term systematic measurements on stream channels throughout the country just to get a similar type thing to the hydrologic gauging station record a geomorphic record of change in different landscapes. And I think that is important and I have made a good part of my career based on channel monitoring (so I am not going to dis it), but I think we also have to look at the monitoring pie as a finite item and how many resources are available and how do we best distribute them to answer and address the issues we really need to address. I think there is some level of stream channel monitoring that is important, but I think we have to weigh it against things that have not been answered and prioritize.

Leslie Reid - I think the point is, Bill brought up a really neat research topic of what does it take for a channel to recover. If we were to sit down and brainstorm an approach to answering that question efficiently what we would probably do is stratify the landscape with the expectation that different units are going to respond in different ways in different time scales. We would probably then look for sites that had undergone a particular kind of disturbance or a range of disturbances and to array our sampling strategy in a way that gives us the likelihood of getting a defensible answer, an interpretable result very efficiently. So if you have a well defined question coming into the monitoring program you can often times develop a monitoring strategy that can answer that question relatively efficiently.

Tom Lisle - Well, I had the luxury of sitting here and thinking of reasons and so I came up with four. Two of them are, Mike distinguished research from monitoring, and so let me start out with sort of the research things - reasons we need to look at channels. One is I think if you look at the array of linkages and processes between things on the hill slope and say fish, I believe the greatest unknown is the physical/biological linkage at the aquatic ecosystem level, how do the physical characteristics of a stream convert to the viability of the species or of the ecosystem as a whole? So in research that is where I think the weakest link is in understanding the system.

The second research problem is the interactions of things that come to the channel, we talked about watershed products (water, wood and sediment), it's valuable to see what the origin of that is and how it is routed through the watershed. But how that plays out in the channel depends on the interaction of these variables and I think we need to know more about that. And I think it is especially important, as Bill has brought up to understand this in time in terms of recovery because it is important to mention the impact on aquatic ecosystem is the duration of that impact and so we need to know that in order to understand the costs of ill advised land-use efforts.

Turning more towards the sort of the monitoring end of things I'd say a land management agency or company might get good use out of channel monitoring. One is we have mentioned that some of the things that end up in channels have a very quick response, so we get an immediate answer to the linkage between hillslopes and channels in terms of turbidity and fine sediment. The problem I would argue also includes sand, temperature, stream flow - these qualities react pretty immediately to changes in the watershed and so they can give timely answers as to what might be going wrong.

Finally, we don't have (especially in private timberland) the luxury of what the Forest Service did in the Northwest Forest Plan. That is, to set aside large riparian reserves and say we are going to just leave things alone and, if we keep the inputs at a natural level the channel will take care of itself. It doesn't seem that the political-economic climate in California is such that we would be able to do that in private timber company land. So this pushes us into knowing more about what these interactions are, how much wood is enough to leave in riparian stands, and so forth. And so this pushes us more towards all sorts of realms of understanding what's going on in the riparian aquatic ecosystem.

Mike Furniss - I guess I am one of the "nay" sayers and I hope that I didn't imply that nobody should be doing channel monitoring because I don't think that is at all true. I totally agree with Leslie and others who said there is a real role for this and lots of values to it. It's just that I have seen a number of proposals that don't seem to fully disclose the limitations or where the method doesn't necessarily match the objective very well or what is being proposed as purpose or an objective would seem to be difficult to meet with that kind of monitoring. I made a distinction between research and monitoring and that's difficult. I'm not sure how useful that is, but if there is a distinction it is not in the rigor that should be applied to design and disclosure of limitations, assumptions, and peer review. They should both have the same kinds of rigor and the same kinds of science content but the client tends to be different, what it is applied to is different. That is, research is applied to advancing our general understanding whereas monitoring is, typically anyway, applied to management or to policy making or to the adaptive management function and that is an important distinction between the two.

Moderator - If I understand Leslie right, I agree, but rather than Simpson doing eight or 10 of these, if there was some trans-ownership ranking maybe five watersheds you are monitoring are very similar so why not do just one, rather than five. So if I am right Leslie, then take that other four you were doing and the money for that and maybe get a little closer to some more personal goals that bind into a regional monitoring.

Leslie Reid - So set up a design of a study, not a design of a protocol. Work out to answer the questions that the study is designed to address or is intended to address, figure out what protocol is appropriate to get to those answers most efficiently, figure out where on the landscape where on the region getting into regional issues those kinds of measurements would most efficiently be made where could you get the most information over a relatively short period, and go at it that way. Yeah.

Moderator - What kind of time frames would you have?

Leslie Reid - Would depend on the question, so there is also the possibility with a lot of this sort of work if you are dealing with recovery there is the possibility of doing some retrospective studies also so that a lot of information is sitting out there on the landscape waiting to be read. There is some neat work that's been done looking at aggradation around dateable vegetation on channel banks to get a handle looking backwards on what rates of channel change, channel morphological change have occurred in these areas.

Bill Trush - Plus what we got on Cañon Creek. You can see it all over the place where alders have come in which tend to root down at the active channel and you can see that there are old bands that are straight and then younger bands of alders that are more concentric as that channels starts to bring back its meander and there are some places on the South Fork Eel you can see 5 generations of alders with each younger generation being a tighter bend following the inside of the active channel and the outside and you can just see it happening, a narrowing of channel. We should go back to that point rather than say start now, that was part of the philosophy that we never really mention we want to start, what I mentioned to Simpson to was, to start back after the '64 or somewhere around there. Let's start there rather than present in our monitoring.

Leslie Reid - Then there is also the issue of recovery. Are we talking about recovery from the 1964 storm, are we talking about recovery from pre-forest practice rules practices, are we talking about recovery from a particular activity at a particular time or a particular? Those are all different aspects of recovery that could be important, but there are probably some of those kinds of disturbances that would be more important to work out a recovery curve for than for others and there the timing of the study, the duration required for the study would be scaled to some extent by the kind of disturbance that you are going to be looking at.

Mike Furniss - Lowell talked about having to have information that is just objective not subject to opinion or needing too much interpretation, because of the credibility factor. I think Tom Lisle's message right off the get go yesterday was that a lot of this stuff really needs interpretation to figure out the interaction of wood and sediment and a whole variety of other things that are going on we need to recognize that the metrics usually by themselves don't tell the story. They have to be combined with careful observation and the narrative that paints a picture of what is really happening and I think we learn all kinds of things about channels, if you have ever been in the field with Trush I mean there is always a story there but the story doesn't always fall neatly into some set of numbers.

Moderator: Question for Mike Furniss

You recommended monitoring driving variables of watershed processes and gave several examples of these, from this list could you identify the specific variable that can be measured with precision and minimal subjectivity and analyzed in a statistically rigorous manner?

Mike Furniss - No (laughing). That's probably too broad a question, or it's a question for everybody. One variable? I am fond of the indicator we call hydrologically connected road or the extension of the stream network caused by road drainage and there hasn't been a lot of work on how to do this, how to get these statistically unambiguous, precise, accurate, results from doing that but I think it is probably possible. You need to go out in the field when it is raining really hard and you will see a lot more connection than you can see from evidence when it is dry and so there is that, but it indicates hydrologic changes that may be attributable to roads systems delivery of sediment and also delivery of applied or accidentally spilled chemicals.

Another point we are always talking about hillslope; upslope versus inchannel but most of the things we talk about as upslope indicators or hillslope indicators are really "up network" they are part of the stream channel. So hydrologically connected roads are those roads that become stream channels when it rains hard. Inchannel is an artificial distinction and I think maybe we've suffered a little bit from that and maybe we ought to say "lower network" and "upper network". We are talking about the stream channel network as the place we usually want to look. It's just that I would kind of push us up to the upper end or make sure we get that as well as the lower end.

Randy Klein - I'd like to second what Mike just said, you could really consider it as the outflow point of everything upstream including channels and hillslopes. For example in your Cañon Creek reach where if you did see aggradation it might not of been from new erosion sources landings and roads but remobilization of sediment stored in the channel and "quasi-storage" areas upstream from that. It is worth exploring all potential sources to really nail it.

Moderator: Question for Leslie Reid

If you set out to measure land use influences upon the impacts of changes in each of the watershed products on downstream resources, where would you do it, where would you measure their interactions? The author admits this is huge question and would appreciate examples.

Leslie Reid - Keep in mind that to get to the interaction part you have to get the watershed products to the place that they are interacting with the organisms that you are concerned about.

The question is how are you going to evaluate the interaction of the watershed product on a particular organism if I understand that right. Correct me if I'm wrong. Is that a fair paraphrase? Could you repeat the question please?

Question is repeated.

Leslie Reid - OK, that wasn't a fair paraphrase because the question was actually involving the land use impacts. So we've got Tom Lisle's flow chart there with land use (lots of boxes, lots of arrows going between the land use and the target resource). The sort of approach that you'd need to take is, first of all look at the strength, the first step is going to be to draw that sort of interaction diagram, to figure out what kinds of mechanisms could be important in the landscape, what kinds of influences and what kinds of interactions could be important.

The second step would probably be to do some sort of a pilot study to figure out which of those arrows should be drawn with felt pen and which of those arrows should be drawn with disappearing ink. So get a feeling for prioritization of the mechanisms.

Third step would be to identify which of those felt pen arrows you know enough about to be able to make inferences about and if you can start to make inferences about them you can start to develop hypotheses the testing of which can tell you if your assumptions are right or not. If one of those strong felt pen arrows is something that you really don't know very much about at all, then you would become very interested in focusing on that interaction as a topic of possibly monitoring and depending on your understanding of the system, maybe a pilot study figuring out if its going to be something that is going to be amenable to being answered through monitoring or amenable to being answered through some sort of retrospective study to start to understand that link in the chain of interactions.

So you basically work through that flow chart in that way. Now when we have looked at those kinds of flow charts they tend to collapse relatively conveniently into a few mechanisms that people can agree, interdisciplinary people can agree and this becomes really, really important because if you have a flow chart like that, you are dealing with hydrology, you are dealing with geomorphology, you're dealing with vegetation dynamics, your dealing with fish biology, you're dealing with entomology you're dealing with a lot of different fields. So that addressing that kind of question is an interdisciplinary effort. But that would be the sort of approach that would most effectively give you the tools for using the information in the future, understanding system.

Moderator: Question open to panel

Can we assess the forest practice rules without establishing physical thresholds?

Mike Furniss - I think we talk about the search for the holy grail, the search for physical thresholds and we haven't gotten very far with that and I don't know how far we are going to get with it. And it often appears we are taking something that is really a policy judgement of acceptable risk or values, political type judgement of acceptable risk and we are not really comfortable with it being that kind of decision we'd like to boil it down to something that is purely technical and that would be nice but I don't think we are going to be able to get to that in many situations. I don't think we need that in order to have monitoring. It makes it easier I think to have statistical power and to know what you are shooting for but it is not necessary in order to get useful results or results that can be meaningful or results that can be applied to that acceptable risk policy decision.

Tom Lisle - A discrete threshold value is very attractive to a regulatory agency agencies because it gives them something that they can be sure of, a concrete measure, but you know if we look scientifically at the variability at how things work in the natural world we don't come across thresholds that apply everywhere and yet we are in many cases in the regulatory business and so how do you deal with this. One way, I like what Steve Ralph was describing this morning, of dividing up the world into topographic-litho regions and I think that could be done in California to some degree. Then within those where we have talked about how each individual watershed even inside one of these regions would behave differently depending on its own peculiarities of history and then eventually we come down to the point where you need to make the call on something whether it is the level of turbidity going to be allowed by the EPA or something like that and you are even after you have broken the world down into smaller and smaller groups, and understand it better and better, I think in many cases you are not still going to arrive at an easily discernible obvious threshold that has scientific merit and at that point you go to an open scientifically informed regulatory framework and say this is what it is for now, and we just have to live with that until we glean more information, greater skill at arriving closer to these thresholds that we can use in regulation.

Leslie Reid - To kind of reiterate what has already been said the threshold definition is a political decision it's a subjective ranking values saying, how much of that is OK? How much is not OK? The example I think that shows it relatively clearly is the one that I showed today where impact was on the Y axis, the exposure to turbidity was on the X axis and there was a continuous curve so there is no level of turbidity that is not potentially having some influence on the organism so that your choice as to where you are going to draw the line is going to be based on an assessment of politically what your value judgment is, of how much is OK for society. I think what then becomes very important is when a threshold is identified through some sort of subjective process that the implications of the selection of that threshold be laid out really clearly just to demonstrate what particular values were weighted against each other and what the likely outcome will be. It would be really convenient if there were a neat physical threshold that said if you stayed below this level everything is going to be just fine and the scientists told us to do that, but I don't know of any system that would apply to.

Phil Kaufmann - I think also there is a kind of a scale issue in the application or enforcement of some kind of a threshold at the level of a site is kind of bound to get us into trouble. The situation reminds me that at any level of fire is detrimental to whoever is burning at the time, yet fire at some level in a bigger landscape is what is going to the allow system to function properly. Similarly any amount of sediment transport/deposition (site-specific) isn't beneficial to bugs, but on the other hand the absence of sediment transport in a system, in a basin, or in a landscape is also detrimental to bugs. Again the same thing, this focus on site-specific for monitoring results or site-specific for application or enforcement is getting us into logical problems.

Moderator – From my perspective, I am still not on the boat that there is a problem. Yesterday was spent trying to justify that there is a problem, exactly what is the problem?

Mary Ann Madej – I think we've altered the landscape away from a natural disturbance regime to a management influenced regime with a lot more disturbance across the landscape in terms of percentage area at any given time. The time-space variation of the processes is what is different. What Bill Trush mentioned yesterday of trying to get the natural processes functioning again would be a big step towards restoring stream channels and salmonid habitat.

Moderator – How do we know what these natural processes were?

Bill Trush – We know that in many parts of our mainstem rivers are now lethal to coho salmon, but probably weren't at one time, otherwise we wouldn't have coho in these watersheds. The problem is we have too few intact watersheds or sub-basins like Elder Creek or upper Prairie Creek to study and determine what are "natural functioning processes".

Moderator – This was supposed to open up more discussion from the panel, any other comments?

Bill Trush - I would add that under the Clean Water Act, there are state-specific water quality criteria for temperature, dissolved oxygen, pH, or sediment that are not being met in over 3,000 watersheds (or sections of rivers), and the list is constantly growing. That in itself indicates to me that there is a serious problem. The water quality needs of salmonids are not mysterious, we know what they are and we know that these standards are not being met in many places.

Moderator - Any other comments?

Leslie Reid – There's another type of problem that I think is important to address. It is the widespread mandate to adaptively manage the landscape with monitoring results, yet there is confusion about what to monitor, how to design a monitoring program, and how to use the results to guide future management. In short, how do you design an efficient, valid monitoring program?

Moderator - That leads into the next question directed at Leslie Reid,Tom Lilse, Randy Klein, Mike Furniss, and Steve Ralph.

What type of monitoring or assessment efforts would you suggest for TMDL compliance in basins such as Redwood Creek?

Leslie Reid – First, what are the issues of concern? Water quality? Biological? Channel morphology? I would look carefully at the kinds of influences and changes likely to occur in the Redwood Creek watershed. If water quality is a major concern, I would advocate some type of turbidity monitoring program. But on the context of hypothesis testing can we define a turbidity signal at the scale of smaller sub-basins to characterize the turbidity "cost" of specific land-use practices?

For other issues, if there's concern about channel change – the downstream methods for monitoring have been taken care of beautifully by RNP or by the methods presented yesterday. I would also stress the importance of looking at the distribution of sediment sources (or potential sources) throughout the watershed. Also an analysis of the relationship between landslides and past and present land-use activities would be useful in determining relative contributions of sediment.

Randy Klein – It's been my education to explain what really is the concept of a TMDL. It doesn't really have much to do with a total maximum daily load of a specific thing, it has to do with the whole suite of processes that happen to pollutants as they move through a stream channel, and how we try to monitor them and attempt to identify relative contributions. In Redwood Creek we also know that one of the big problems is the estuary and the simplification of habitat caused by the levees. We need to make sure that in the TMDL process we're not too focused, on say sediment, when there are other problems limiting salmonid production unrelated to the input of sediment or thermal loading.

Mike Furniss – One of the roles that was envisioned for watershed analysis (not sure we've succeeded) was to help to arrive at the best parameters to monitor. I think in Redwood Creek we're well positioned to take full advantage of our understanding of the watershed, which is as good as there is for a watershed of that size, and let that drive the design of the monitoring that Leslie mentioned. What are the mechanisms that are impacting the things we care about, and what is the best way to keep track of those things? I like to think of TMDL more as Total Maximum Daily Roads, or Total Maximum Daily Landslides.......looking at the loading of sediment from the source areas. Same story, broken record.......

Moderator: Question for Lowell Diller.

What feasible mechanistic hypotheses are the FFFC considering as it develops the channel monitoring methodology?

Lowell Diller – As far as I'm concerned I don't think the FFFC has developed any yet, for the most part it is beyond our expertise. I think the FFFC needs to look for assistance from some of the experts on this panel and possibly in the audience today. The FFFC has concentrated on adopting or developing protocols to standardize data collection that has utility to land managers. Eventually the group needs the input of experts to develop the hypotheses to test using the channel monitoring protocol.

Moderator: Question for Steve Ralph.

You showed a turbidity plot on discharge where there was a greater than 20% above background level post-management, this notion is relative to TMDL's on the north coast, is level applied in other regions? Is this the only justifiable measure of turbidity available as a threshold?

Steve Ralph – I don't think it was my graph.

Moderator – it was presented in Leslie's talk, but the question is for you. How else can turbidity be used for establishing compliance monitoring thresholds?

Steve Ralph – I must confess that until last week, I was in the camp of turbidity being yesterday's news. After attending yesterday's session and hearing from some of the others, I'm ready to reconsider the applicability of turbidity monitoring as a useful tool. I guess I don't have specific ideas at this time, but do plan to reconsider its use. As a caveat, in some of the basins I work in, from personal experience I would say that turbidity is not an issue, or at least not the primary impact to stream health. In some cases, bed scour and fill at redd locations is a more significant limiting factor in survival to emergence and ultimately in smolt production.

Moderator: Question for Leslie Reid.

Please recap the biological effects of turbidity and the limitations in assessing the effects of broader sediment issues to salmonid life-histories, such as alteration of habitat and spawning success, what are we missing when we only look at turbidity?

Leslie Reid – We're not only looking at turbidity, ever. There are lots of factors and processes to consider. Remember, there are lots of things to measure, some things we should measure, and a few things we can feasibly measure (that have relevancy to the specific watershed of interest). Need to identify ahead of time the relevant issues and processes, and then select the parameters to measure (given "real-world" budget and time constraints). Must pick and choose what will give you the most effective information for the funding available. Never an issue of measuring just one thing, must select the parameters that will yield the most beneficial interpretable information to make wise land management decisions regarding the issues at hand.

Tom Lisle - I think we need to get away from the notion of the "parameter of the year", especially when you attend meetings such as these. The message here is, hopefully there are no magic bullets that will instantly solve your management issues across all watersheds (and never will be). I think you need to keep your management tackle box fully stocked and be ready to employ different techniques as the situation calls for. Just because one parameter is useful or not in one watershed has little bearing on its utility in another location.

Bill Trush – One of the things the FFFC focused on too, was what is the meaning of all this in a limiting factors analysis of coho production from smaller tributaries, that is tying it all back to some type of juvenile population estimate. People are worried by about fish. In Elder Creek, I saw that you could have five times as many adult steelhead spawning, but it appeared to make little difference in the numbers of smolts (2+ fish). It seems there's the need for eventually having a limiting factors model, especially if the only thing going on in California is seeing if a model developed in Oregon is applicable down here. I think eventually we need to look at the ratio of out-migrating smolts to adult returns (for each brood-class) to provide insight to factors limiting production. Some of the work done by Frank Ligon on the Tuolumne River showed there was a relationship, and in some years there were too many redds and this resulted in a drop in subsequent adult returns.

Lowell Diller – Some of us recently attended a population viability analysis conference in San Diego, and several of the limiting factors models presented looked at ocean productivity and concluded it was over-riding to anything occurring in the freshwater habitat. This leads to one of the concerns as managers of lands with freshwater salmonid habitat - that changes in management practices and recovery of these habitats may not lead to increases in population numbers as long as ocean productivity remains poor. One of our long-term objectives is we want the monitoring to show that our management may lead to improvement to physical measures of the channel, yet may not lead to the recovery of salmonid populations (or be the best indicator of timber management, or its effect on watershed recovery).

Mike Furniss – I'm still fond of the notion of turbidity levels up to 20% above background as a standard in the basin plan. It is interesting to note that there has been very little testing of that in the field. What does that mean? Has it been dismissed as ineffective, or we haven't gotten around to the monitoring, or what? Fish isn't the only issue here, in the Mad River it is also our water source, the amount of chlorine used in it directly proportional to the amount of turbidity recorded at the control plant where the water is taken. It has merit and turbidity monitoring is something we need to look at closer.

Randy Klein – The next question then is to ask, 20% above what? Establishing background levels is difficult, given the wide range of geologic conditions, erosive hillslopes, and levels of precipitation. How do you determine natural, background levels (or background ranges of variability)? Even in relatively undisturbed (and adjacent) watersheds such as Prairie Creek and Little Lostman Creek, there are differences in parent rock-type which was apparent by very different turbidity signals, and ranges of variability. One thing the two streams have in common is that they clear very rapidly after storms compared to managed streams in the nearby area.

Leslie Reid – This is where the issue of chronic turbidity exposure is important, what is the duration, as well as the concentration? Looking from the viewpoint of the fish, if you have to hang tight for a few hours or days until water quality improves, that's much better than prolonged exposure over weeks or months at a time. Another important point made by Randy is that you can stratify the landscape by geology and deal with a certain portion of the natural variability. You can also stratify the hydrograph and account for some of the variation too.

Beyond just measuring turbidity levels, we need to also look at the response of the fish to changes in flow and turbidity. In the Clearwater River many juveniles migrated into smaller, clean-running tributaries during high flow events, channels we might call Class 2 or Class 3 channels in California because they are dry in the summer.

Mike Furniss - I think sometimes we are too pre-occupied by the large events, the pulse disturbances that re-set watershed conditions (cause landslides and dramatic channel changes), and not enough with the smaller, less dramatic events that chronically occur and may biologically have a greater negative impact on salmonids.

Moderator: Question for Phil Kauffman.

When is EMAP coming to California?

Phil Kauffman – There was a regional project in the central basin of California that is now just starting to analyze the data that was collected two years ago. There is some reconnaissance-level work being conducted in 13 western states where now decisions are just being made on what information to collect and how to collect it. Field work would probably occur starting at the end of 2000.

Moderator – In closing I would ask Mike Furniss and others who are suggesting additional, up-network parameters for investigation to supply the FFFC with these suggestions. We would post these on our website and also use these to guide future technical and policy decisions. I think the FFFC is ready to step back and re-examine the protocol development done to date, and focus harder on setting objectives for both short-term and long-term monitoring and management needs.

Does anyone have anything to add to summarize where the channel monitoring protocol is, and what we have accomplished over the past two days?

Trent McDonald – There are several things that I think are needed: A further assessment of reach location, what to measure, and how to analyze. The variables we have used so far may or may not be the best ones to use. It would be helpful if everyone around this table picked out the one metric they feel is best and just write it down.

Steve Ralph – This gets back to it is difficult to do that type of exercise without knowing what the specific monitoring objectives are and the major channel forming processes involved in a specific watershed. For example, a hammer is a great tool, but I wouldn't recommend using one to repair a watch. I would suggest that the FFFC step back and evaluate the objectives more carefully and draw on the knowledge of the local watershed and geomorphoric experts who presented information over the past two days.