Monitoring Design for the Forestry Module of the Governor's Salmon Recovery Plan

July 2002

MEMORANDUM

To: **CMER, FFR Policy**

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Subject: **Release of MDT Report**

Date: **October 20, 2006**

The MDT was commissioned by Forest and Fish policy to "develop a comprehensive framework for collection, analysis and interpretation of data related to effectiveness monitoring" for rules derived from the Forest and Fish Report (1999). A preliminary report defining our conceptual approach was distributed to CMER in November of 2000. This report builds from that initial report.

It is important to recognize that this report is very much a work in progress. While a group effort, our approach utilized the expertise of different team members by directing members to work independently or in subgroups on elements that fit their expertise.
Since the release of the initial overview document, the MDT met regularly to coordinate efforts and MDT members began work on aspects of the design, either independently or in subgroups. A draft was submitted to the Independent Science Panel (ISP) for review in December of 2001. The ISP completed their review January 30, 2002. The document was revised and released in July 2002.

The report is a conceptual framework for a coordinated monitoring plan with specific examples of how specific types of monitoring may be conducted. The examples of extensive riparian monitoring and fish passage monitoring were meant to provide the initial draft that would (and has been) be modified by the appropriate Science Advisory Group within CMER. The mass wasting section was never completed for this report but will be addressed within CMER.

We release this draft today with the intent of providing the MDTs collective vision for how an effective monitoring program could be structured and to begin discussions and interactions with a broader community on these ideas. Our vision is that this report will continue to change as new components are developed, methods are tested, modified and improved, new technologies become available, and the availability of resources changes over the years. With critique from the larger CMER world we anticipate this report will come better. Please direct comments to Dr. Timothy Quinn-WDFW (quinntq@dfw.wa.gov ph 360 902 2414). Written comments, either email or hardcopy, are preferred.

Monitoring Design for the Forestry Module of the Governor's Salmon Recovery Plan

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Executive Summary

This report was created by the Monitoring Design Team (MDT), which was formed in August 2000 to provide an overall design of the monitoring program for new forest practice rules based on the Forest and Fish Report (FFR). The monitoring program is the scientific part of an adaptive management program outlined in the FFR. This document provides a general plan for that monitoring program.

This monitoring design has three distinct but related components:

1. *Prescription monitoring* is used to evaluate the effectiveness of individual FFR prescriptions under a range of different physiographic conditions and evaluate alternative treatments for meeting resource objectives. Prescription monitoring consists of tracking the performance of individual or groups of prescriptions by measuring input processes and/or habitat indicators.

2. *Extensive monitoring* is used to evaluate the current status and future trends of key indicators of important input processes and habitat conditions statewide.

3. *Intensive monitoring* is designed primarily to address the cumulative effects of multiple forest practices. Intensively monitored watersheds could also be used to validate Performance Targets and conduct applied research by concentrating monitoring and research efforts in a single location.

Prescription monitoring will consist of active manipulation and monitoring to examine the effectiveness of specific treatments and alternative treatments. These projects will examine multiple effects where feasible but generally will have a narrow focus. Individual monitoring projects will be prioritized and developed within the Science Advisory Groups of CMER. An example is the influence of riparian harvest prescriptions on Type N stream temperature. Each experimental design and monitoring approach may vary substantially among effects examined and the prescriptions being monitored. Biological parameters will generally not be measured during prescription monitoring activities. Biological data are generally difficult to interpret at finer monitoring scales.

Extensive monitoring is a population-scale assessment of the effectiveness of FFR rules in attaining specific Performance Targets across FFR lands. Where Prescription Monitoring will estimate the effects of a specific prescription at that site, Extensive Monitoring estimates the distribution of conditions across the landscape regardless of management history as FFR rules are applied and represents the ultimate test of whether FFR rules are effective in meeting the conditions needed to protect salmon and other protected species. Four areas were selected for extensive monitoring: stream temperature and riparian stand characteristics; barriers to fish passage; forest roads, and mass wasting. Only the first two are presented in this document. Both forest roads and mass wasting monitoring plans are still under development and will be included in later versions.

Intensive monitoring will enable the evaluation of two important aspects of the effectiveness of forest practices that cannot be addressed with other approaches; cumulative effects of multiple practices and biological responses. Evaluation of cumulative effects of multiple management actions on a system requires an understanding of how individual actions influence a site and how those responses propagate through the system. This understanding will enable the evaluation of the effectiveness of management practices applied at multiple locations over time. This sophisticated level of understanding can only be achieved with an intensive, integrated, monitoring effort. Evaluating biological responses is similarly complicated, requiring an understanding of how various management actions interact to affect habitat conditions and how system biology responds to these habitat changes.

The sampling unit for intensive monitoring should be an entire Watershed Administrative Unit to encompass the full range of habitats required for salmon to complete freshwater rearing because this is the smallest experimental unit at which a comprehensive evaluation of the effect of FFR on these fish can be conducted. Biological responses of other groups of organisms could be adequately conducted at smaller scales but given the focus of FFR on improving the production of salmonid fishes, these animals should be included in the evaluation process. In addition, this relatively large area provides the opportunity to evaluate physical, chemical and biological effects of FFR at hierarchical spatial scales ranging from the reach through sub watersheds of the WAU to the entire WAU.

In order to obtain adequate representation of conditions in forested areas across the state, ideally, an intensively monitored WAU would be located in each ecoregion that contains a significant amount of forest land that will be managed under FFR. The WAUs selected within each ecoregion should contain conditions representative of the key sensitivities occurring in that area. For example, a WAU selected for intensive monitoring in southwestern Washington should contain areas prone to management-induced landslides, as this is a key issue FFR attempted to address and a common problem in this region. Similarly, as bull trout are a key concern in eastern Washington, WAUs selected for intensive monitoring in these ecoregions should contain this species in order to evaluate it's response to the prescription package.

Development of ecologically relevant measures to evaluate monitoring results should be incorporated into the adaptive management program. Use of rigid criteria is normally only appropriate for prescription effectiveness monitoring where the desired response can be very precisely defined. For extensive monitoring and for most types of intensive monitoring, use of a specific standard is usually inappropriate. Measures of ecological condition must account for the complex array of conditions required to support biological diversity at multiple scales of space and time and the dynamic processes that create and maintain ecologically complex and resilient watersheds (Bisson et al., 1997). These will focus attention on the real objective of FFR; conducting commercial forestry in a manner that conserves the processes that support aquatic productivity and diversity.

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Introduction

This report was created by the Monitoring Design Team (MDT), which was formed in August 2000 to provide an overall design of the monitoring program for new forest practice rules based on the Forest and Fish Report (FFR). The monitoring program is the scientific part of an adaptive management program outlined in the FFR. This document provides a general plan for that monitoring program.

This report contains the following elements:

- *Background* – briefly describes the development of the FFR and new forest practice rules.
- *FFR Adaptive Management Program* – describes the intent and organizational components of the FFR adaptive management program.
- *MDT Monitoring Approach* – describes the MDT mission and approach to developing an integrated monitoring program support of adaptive management.
- *Monitoring Design* – describes the proposed monitoring approach.

Background

In 2001, the Washington State Forest Practice Board approved a comprehensive set of new forest practice rules. These rules govern forest management activities on private and state forestlands. The intent of these rules was to:

- Provide compliance with the federal Endangered Species Act for aquatic and riparian-dependent species on non-federal forest lands.
- Restore and maintain riparian habitat on non-federal forest lands to support a harvestable supply of fish.
- Meet the requirements of the federal Clean Water Act for water quality on non-federal forest lands.
- Keep the timber industry economically viable in the State of Washington (WFPB, 2000).

The new forest practice rule package was largely based on the Forest and Fish Report (FFR), which was the negotiated agreement among private forest landowners, federal and state and local governments, and certain Indian tribes (hereafter stakeholders). Stakeholders used the Timber, Fish, and Wildlife (TFW, 1988) consensus-based process for negotiating and resolving conflicts related to protecting public resources (fish, wildlife, water quality and quantity, and archeological and cultural spaces) while maintaining a viable private forest products industry in Washington State (TFW, 1988). FFR negotiations began in 1998 and were finalized on April 29, 1999. The Washington Legislature (Engrossed Substitute House Bill 2091, i.e., Salmon Recovery Bill) strongly encouraged the Forest Practice Board to follow recommendations contained in the FFR to develop new forest practice rules. Following additional work by stakeholders, preparation of an EIS (WFPB, 2001) and consideration of public comments, the Forest Practice Board approved final rules on May 17, 2001.

The FFR was recognized as a negotiated agreement for which recommendations derive from both "science" and "policy"[1] (CH2MHill, 2000; Fairweather, 2001; Goldman, 2001; Goos, 2000; Independent Science Panel, 2000a; and WSR, 2001). FFR is the basis for the private and state forest habitat component of the Statewide Strategy to Recover Salmon (JNRC, 1999) and addresses privately owned and state administered forestlands not covered by Habitat Conservation Plans. More background on the impetus behind new rule adoption, the process used to adopt new rules, their intended result, and their scientific basis can be found in CH2MHill (2000), Fairweather (2001), FFR (1999), Goldman (2001), Goos (2000), JNRC (September 1999), WFPB (2001), and WSR (2001).

[1] In reviews of FFR content, "science" is typically used in reference to ecological considerations that are (usually) based on research findings or inferences made on how ecological systems can be expected to operate. "Policy" typically refers to social and economic considerations reflecting stakeholder goals, balanced against their perception of political realities, their interpretation of scientific findings, their analyses of economic impacts and the decision space these leave to forge acceptable compromises.

FFR Adaptive Management Program

New forest practice rules derived from FFR establish an adaptive management program. "The purpose of this program is to provide science-based recommendations and technical information to assist the [forest practice] board in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve resource goals and objectives" (WAC 222-12-045) (Appendix A). The adaptive management program is composed of the following elements:

1. The identification of key questions and resource objectives.
2. A set of protocols and standards to define and guide execution of the process.
3. A set of participants empowered to conduct the required activities.
4. A baseline data set used to monitor change.
5. A formalized dispute resolution process.
6. Funding adequate to conduct the necessary research, monitoring, and peer review**.**

The FFR adaptive management program was intended to include all components necessary to test the effectiveness of new rules and adopt new rules as appropriate based on new science.

Some but not all elements described in the FFR adaptive management program were in place as a result of previous work done by TFW (TFW, 1988). TFW, formed in 1988, was composed of a policy group that provided oversight to a number of other technical groups including the Cooperative Monitoring, Evaluation, and Research Committee [CMER]). CMER had a history of conducting applied research (in the name of adaptive management) and contributing new science to the Forest Practice Board under the direction of the policy group. For example, CMER helped develop Watershed Analysis and forest practice rules for protection of Northern Spotted Owls and Marbled Murrelets (FFR, 1999). Much of TFW's work prior to FFR was meant to improve forest practices on a site-specific basis (see section on monitoring types) by measuring the effects of different types of rule prescriptions on particular indicators, e.g., the effect of canopy shade on stream temperature. CMER work also focused on the development of management tools such as the surface erosion module in watershed analysis, the mass wasting screen, and the development of protocols for collection of data. However, several of the six elements of the adaptive management outlined above were missing or only loosely organized in TFW prior to the FFR.

FFR Adaptive Management Outcomes

One of the most important, new elements of FFR adaptive management was the development of specific resource-based resource objectives. Prior to FFR, performance measures were loosely based on the broad goals articulated in the TFW agreement of maintaining a viable timber industry while protecting cultural resources and habitat for fish and wildlife with little other, more specific guidance. In contrast, measures of FFR success are hierarchical and phrased in terms of a single Overall Performance Goal at the highest level of organization followed by

Resource Objectives and finally Performance Targets. The FFR Overall Performance Goal states that "Forest practice, either singly or cumulatively, will not significantly impair the capacity of aquatic habitat to: a) support harvestable level of salmonids; b) support the long-term viability of other covered species; or c) meet or exceed water quality standards."

Under this Goal are Resource Objectives, one each for heat input, large woody debris/organic inputs, sediment inputs, water inputs, and chemical inputs. Finally, under each Resource Objective are Performance Targets, which are measurable criteria that define specific targets for forests conditions and processes. By meeting Performance Targets, it is assumed that objectives will be met. Likewise, by meeting all objectives, it is assumed that the overall Performance Goal will be met. To follow one example, the Resource Objective for sediments inputs is to: "Prevent the delivery of excessive sediments to streams by protecting stream bank integrity, providing vegetative filtering, protecting unstable slopes, and preventing routing of sediments to streams". The Performance Targets for sediment input from new roads is "Virtually none". Best management practices in the form of specific forest practice rules for roads are designed to meet that Performance Targets. All FFR Resource Objectives and Performance Targets are listed in Appendix B.

The Overall Performance Goal, Resource Objectives, and Performance Targets were the results of negotiations based on scientific, political, and economic considerations. The science used in support of these measures ranged from being relatively well understood (e.g., defining the relationships of stream temperature to air temperature) to poorly understood (e.g., effect of discontinuous riparian buffer on viability of headwater stream amphibians). Performance Targets were often considered to be the most important criteria by which stakeholders would measure FFR success since they are the quantitative (measurable) linkages to the goals and objectives.

FFR authors understood the need for measurable criteria as Performance Targets, even in circumstances where some disagreement existed about the exact target language or how targets were expressed (e.g., as a point estimate rather than as a frequency distribution (see section on *Performance Targets: evaluating monitoring results* below). When appropriate Performance Targets were unknown, targets often were expressed in terms of a rule prescription rather than in terms of resource outcomes. For example, the "litter input" Performance Target for western Washington non-fishbearing perennial streams is "at least 50% of recruitment [of litter] available from within 50' [of the stream]", which is nothing more than a restatement of the rule that requires at least 50% of the total length of that stream type to be buffered by a no-harvest buffer 50 feet on each side of the stream. In some cases, time frames were an implicit part of Performance Targets, even though these time frames are often found in other parts of the FFR. For example, all fish passage barriers are to be corrected in 15 years (since rule adoption), and road maintenance and abandonment plans must be completed by year 5, with all corrective actions completed by year 15. In other cases it is unclear when Performance Targets are to be reached. The result is a variable set of Performance Targets tested at different spatial and temporal scales with many linked indirectly to the salmon, water quality and other public resources.

Ideally, determining effectiveness in a monitoring program should be based on predefined and measurable criteria (e.g., FFR Performance Targets). Measurable criteria form the basis of testable hypotheses and can easily be linked to policymakers' expectations. The MDT was tasked with designing a monitoring program to demonstrate the effectiveness of a negotiated set of forest practices, applied to diverse landscapes with differing land use histories within a time frame needed by regulators and politicians. Unfortunately, authors of the FFR lacked information necessary to create meaningful Performance Targets in some cases. For example, the Performance Target for litter input does not lend itself to an effectiveness monitoring hypothesis. The MDT recognized that an overall monitoring design would need to address those cases where information gaps prevented the creation of Performance Targets suitable to effectiveness monitoring. In other words, monitoring must address the need for formulating appropriated Performance Targets where they are missing as well as testing the effectiveness of existing Performance Targets. The MDT's intent was to build a monitoring program that is flexible enough to deal with these contingencies while allowing scientists to learn about processes that effect aquatic ecosystems.

The MDT's Role in FFR Adaptive Management

The MDT's task was to develop an integrated monitoring approach that provided a framework for collecting new information to support the adaptive management program. This approach was built upon the following guiding principles:

1. Monitoring must attempt to determine cause-and-effect relationships between a particular forest practice and input processes (i.e., large woody debris, hydrology, chemical, nutrients, sediment, and heat).
2. Monitoring must attempt to determine cumulative effects of all forest practices combined on aquatic resources.
3. Monitoring must provide stakeholders with information on how FFR prescriptions are working across the state.
4. Monitoring should provide clear linkages between compliance, effectiveness, and validation monitoring.
5. Monitoring needs an active research component to facilitate rapid feed-back for modifying specific management actions and a passive component to monitor the effects of all FFR prescription on the status and trends of aquatic resources.
6. Monitoring should test whether less costly alternative prescriptions would be effective in producing conditions and processes that meet resources objectives or where more conservative prescriptions may be necessary.

The MDT did not consider all scientific activities that may be necessary to support the adaptive management program of the FFR. The MDT did not explicitly consider the development of implementation tools (e.g., model to predict upstream extent of fish) and some types of validation monitoring while recognizing that these efforts are essential to the success of the adaptive management program. The MDT believes that CMER is the appropriate venue to develop those monitoring elements. However, the MDT believes that our work will help better define when and where those adaptive management components are necessary and how they will be integrated into an overall monitoring design. Similarly, the MDT did not consider the organizations structure of the adaptive management program and believes that our work will help better define when and where those adaptive management components are necessary and how they will be integrated into an overall monitoring design, how different groups within TFW are to interact, or how new information was to be used by FFR policy makers or the Forest Practice Board. The MDT recognizes that FFR policy and the Board are ultimately responsible for overseeing the monitoring program and ensuring that new data is appropriate to goals of the FFR.

Monitoring Types and Variables

Three commonly described monitoring types are (Botkin et al., 2000; Independent Science Panel 2000; Mulder et al., 1999):

1. *Compliance monitoring* is used to confirm that management actions were implemented as prescribed.
2. *Effectiveness monitoring* is used to test if prescriptions are effective in producing conditions and processes that achieve resource objectives. FFR Performance Targets, which are linked to resource objectives, are generally measured by quantifying input processes or attributes of physical habitat.
3. *Validation monitoring* is used to validate or verify the assumptions underlying the targets by linking changes in input processes or physical habitat to the response of biota (e.g., fish, invertebrates, amphibians).

Each monitoring type is typically associated with measuring specific types of variables (Figure 1). Compliance monitoring is arguably the most straightforward in the sense that rule language *is* the Performance Target. Because rules require enough specificity to be implemented by managers, rule language is often very explicit and tends to become even more explicit over time, as rules are applied to an increasingly wide range of situations on the ground. Compliance monitoring is a critical component of the overall monitoring program since both lack of prescription effectiveness (ineffective rules) and non-compliance can result in the same outcome.

Effectiveness monitoring typically measures input processes or attributes of physical habitat. These types of process or habitat-based monitoring presume that one can measure indicators that reflect underlying ecological processes to which species respond; and inferences can be drawn between habitat indicators and the actual response of biota (Noon et al., 1999). The premise of habitat-based monitoring is that animals respond to structural and compositional features of the landscape in which they evolved (Noon, 1986; Noon, 1997) although Botkin et al. (2000) noted that without validation monitoring the validity of theorized relationships between habitat and response of salmonids will remain unknown. In some cases, input processes, rather than habitat attributes, are monitored because they correspond more closely to a FFR Performance Target, are more indicative of the intent of the actual rule, or because the input process was more sensitive to the intended changes in rules than either habitat indicators or biota. For example, the intent of disconnecting forest roads from the stream network was to reduce the impact of road runoff to stream hydrology and to reduce the quantity of fine sediment reaching the stream. The ratio *road miles draining to streams: miles of stream* was chosen as the Performance Target

(Appendix B) because measuring other related variables (e.g., stream flow, sediment load, habitat, biota) at more than a few sites would be too costly.

Tracking habitat indicators or input processes typically costs less and is often easier than counting individuals of a particular species. Habitat monitoring also can be directed at indicators commonly measured for other purposes, (e.g., management), and often have data collection protocols already established (Noon, 1997). Monitoring habitat indicators in forested environments will also fill an important gap in that monitoring salmonids in the Pacific Northwest under the ESA has focused primarily on their population characteristics with no comprehensive habitat monitoring counterpart (Independent Science Panel, 2000c). The MDT expects that population monitoring (smolt and spawners) will be a key feature of other monitoring efforts, conducted at scales appropriate to answer questions related to recovery of stocks or ESUs. Measuring habitat is also an important part of quantifying the recovery process over which forest landowners exert some control. The MDT recognizes that salmonid and amphibian populations may decline due to conditions outside the control of forest landowners, even when habitat conditions in forested areas are improving. Documenting changes to habitat condition provides important information regardless of how fish and amphibian population status respond.

Validation monitoring is the most complex and ambitious type of monitoring because it attempts to measure the response of biota to management actions that affect habitat and input processes. Because one of the key purposes for establishing a monitoring program is to provide assurances to federal and state agencies that conditions are improving for threatened and endangered species, validation monitoring is crucial to the MDT study design. While ascribing cause and effect by solely measuring population performance may be difficult, demographic parameters are the best indicator of the overall success of how species are responding.

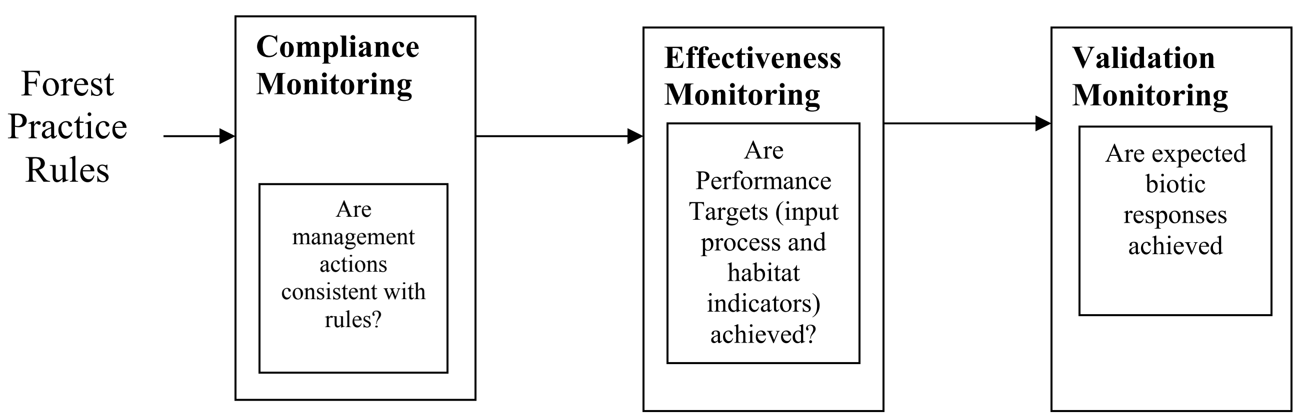

Figure 1. The links among monitoring types and Forest Practice Rules. The primary objective of each monitoring type is shown in the boxes. Please see text for further explanation.

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MDT Monitoring Approach

Responsibility for compliance monitoring rests with the Department of Natural Resources (WAC 222-08-035) and so our approach focuses exclusively on effectiveness and validation monitoring. Effectiveness and validation monitoring depend on having a rigorous compliance monitoring program. Understanding the effectiveness of rules is impossible without first knowing that those rules were implemented according to prescriptions.

As discussed above the FFR lists the Performance Targets for each resource area and prioritizes a number of effectiveness monitoring and validation monitoring questions for each (Appendix B). The questions vary from specific (testing the effectiveness of a specific riparian buffer in meeting shade targets) to broad (are Performance Targets met statewide) and span a wide range of spatial and temporal scales. However, except for the development of specific tools (e.g., stream typing), the questions generally fall into one or more of three categories.

- Are Performance Targets being met across state and private forestlands?
- Are FFR rules (current or alternative) effective in meeting Performance Targets at or near the harvest unit?
- Are the Performance Targets appropriate to meet the Resource Objective and the Overall Performance Goal?

This monitoring plan is organized to address these questions in specific resource areas and provides a framework for the integration of complementary studies across spatial scales. Impacts to some resource conditions (i.e., input processes, habitat indicators, and biota) such as stream temperature, are evident immediately post-harvest, while other impacts, e.g., increased mass wasting events or loss of LWD, may not be evident for years and may take decades to detect. The wide range of spatial and temporal scales, questions that range from the general to the specific, and uncertainty related to the Performance Targets require a multi-scale monitoring plan where key indicators are tracked at one or more spatial scales depending upon the specific objectives for that indicator.

This monitoring design has three distinct but related components:

1. *Prescription monitoring* is used to evaluate the effectiveness of individual FFR prescriptions under a range of different physiographic conditions and evaluate alternative treatments for meeting resource objectives. Prescription monitoring consists of tracking the performance of individual or groups of prescriptions by measuring input processes and/or habitat indicators, and where feasible could be used to assess the local response of biota.
2. *Extensive monitoring* is used to evaluate the current status and future trends of key indicators of important input processes and habitat conditions statewide.
3. *Intensive monitoring* is designed primarily to address the cumulative effects of multiple forest practices. Intensively monitored watersheds could also be used to validate Performance Targets and conduct applied research by concentrating monitoring and research efforts in a single location.

These relationships between compliance, effectiveness, and validation monitoring types and the MDT components are shown in Figures 2 and 3.

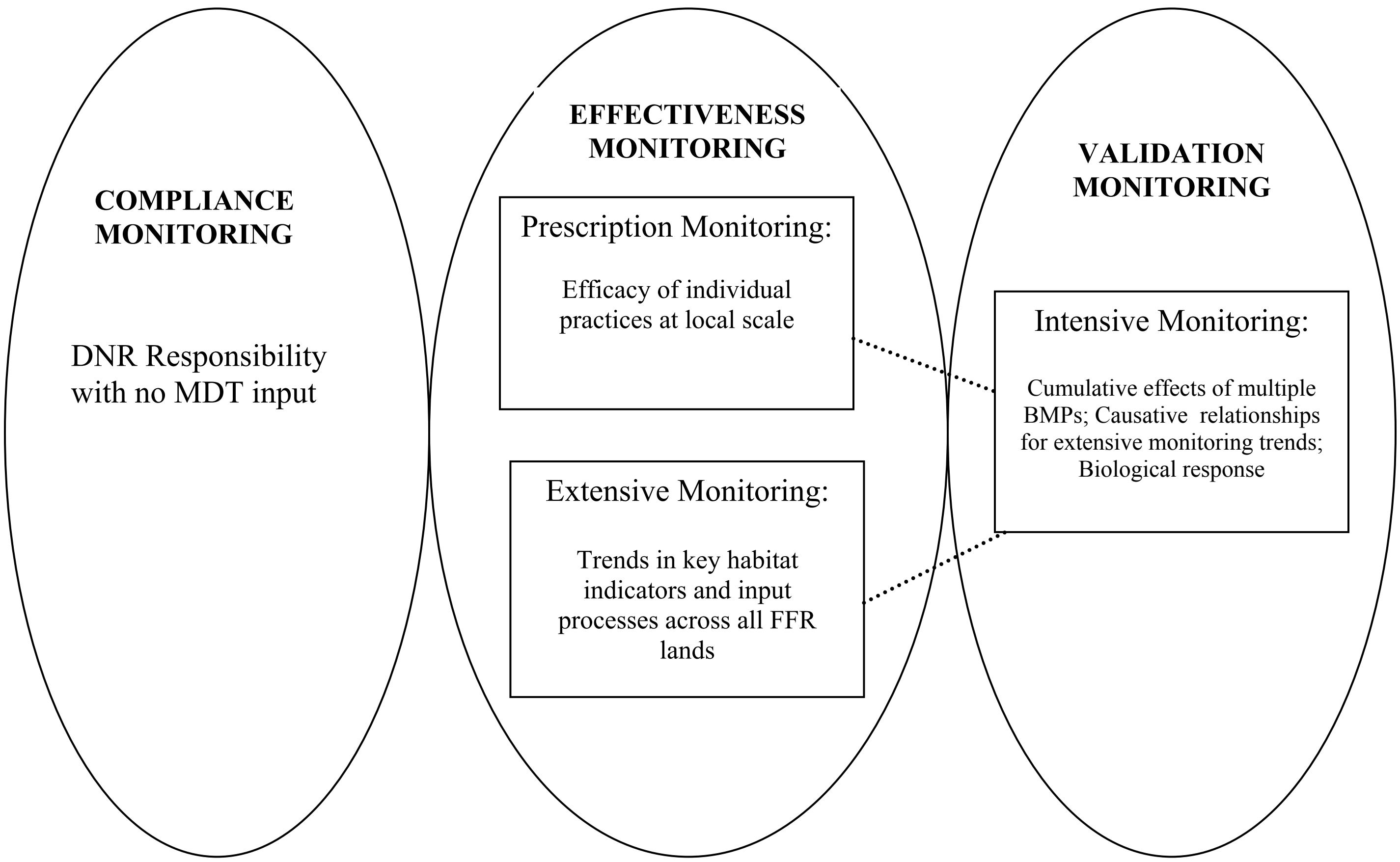

Figure 2. Relationship among compliance, effectiveness, validation monitoring, and monitoring proposed by the MDT. Prescription and Extensive monitoring are subsets of Effectiveness Monitoring, while Intensive Monitoring is a subset of Validation Monitoring but could also include some types of Prescription and Extensive monitoring. The primary objective of each monitoring component is shown in the boxes. Intensive monitoring provides the link (shown as dotted line) between the fine-scale information about individual prescriptions and the large-scale, long-term trends in resource conditions determined by extensive monitoring. Including the intensive monitoring piece enhances the value of information collected at the other two scales. Resource conditions include habitat indicators (e.g., large woody debris in streams) and input processes (e.g., rate of fine sediment delivery to streams). See text for further explanation.

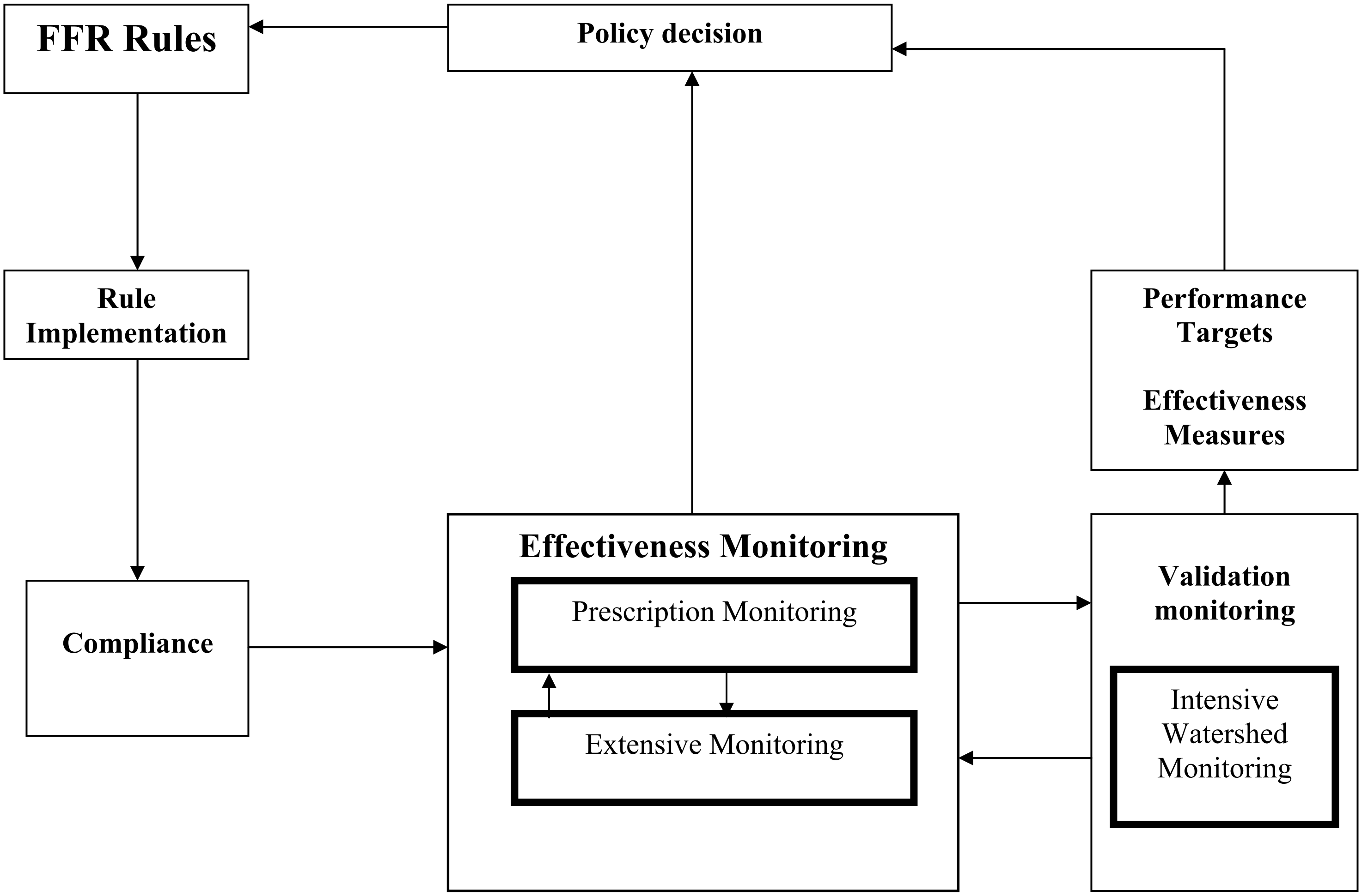

Figure 3. Conceptual relationship of the MDT design to assumed FFR adaptive management process. MDT pieces are outlined in heavy line. Prescription and extensive monitoring are part of effectiveness monitoring. Performance targets are expected outcomes of new forest practice rules and benchmarks for measuring rule effectiveness. Validation monitoring can be designed to validate the relationship between performance targets and biologic or resource impacts (is this the correct target), or to verify assumptions underlying the targets (is the correct thing being measured?).

Evaluating Monitoring Results

Usually, the objective of monitoring in an adaptive monitoring program is to determine whether or not a management action achieves some desired outcome. In order for the monitoring data to address this question in a manner meaningful to managers, the desired outcome and how the monitoring results will be judged against that standard should be established during the formulation of the monitoring plan. This desired outcome may be characterized in a variety of ways:

- An established regulatory standard.
- Conditions deemed appropriate for a species of interest.
- Conditions at a site relatively unimpacted by human actions.
- A desired trend in an attribute or process.

Each of these approaches has some relevance in evaluating monitoring results. In general, the first two outcome types have been most frequently applied but are generally less realistic from an ecological perspective than outcomes that acknowledge the diversity and variability in natural systems. Use of rigid criteria is normally only appropriate for prescription effectiveness monitoring where the desired response can be very precisely defined. For extensive monitoring and for most types of intensive monitoring, use of a specific standard is usually inappropriate. Strict standards are not available for many of the ecological attributes and processes addressed by FFR and even where standards do exist, their biological relevance is often questionable. This approach to evaluating ecological condition does not account for the complex array of conditions required to support biological diversity at multiple scales of space and time; simple standards cannot encompass the dynamic processes that create and maintain ecologically complex and resilient watersheds (Bisson et al., 1997). Thus, using simple standards and thresholds to evaluate monitoring results will often divert attention from the real objective of FFR; conducting commercial forestry in manner that conserves the processes that support aquatic productivity and diversity.

Outcomes based on conditions in unmanaged landscapes may be more ecologically relevant if these outcomes are expressed at appropriately large scales of space and time. Large spatial and temporal scales are required to account for the variety of conditions generated by natural processes of disturbance and recovery in unmanaged landscapes (Reeves et al., 1995; Bisson et al., 1997). However, the time required for habitat attributes within a managed watershed to achieve a range of conditions comparable to those exhibited by an unmanaged system can make this approach infeasible. For many of the parameters that will be measured in this monitoring effort, a desired range of parameter conditions coupled with a predicted rate of change from current to desired condition can be used as an interim standard. A standard expressed in this manner has the advantage of providing meaningful feedback on the efficacy of prescriptions much faster than simple comparison to a fixed set of endpoint conditions. Thus, in many instances expressing a desired outcome in terms of a trend through time in a parameter is most appropriate for interpreting monitoring results.

Combining the range and frequency of conditions at unmanaged sites with the expectations incorporated in the FFR prescriptions can be used to estimate the direction and rate of change to be expected with the application of prescriptions. Many of the FFR prescriptions were designed to enable certain habitat attributes to ultimately attain conditions approaching those in unmanaged systems. For example, under FFR prescriptions wood produced by riparian forests along fish-bearing channels is predicted to provide at least 85% of the wood generated by unmanaged forests. Similarly, prescriptions addressing mass wasting are intended to reduce the occurrence of hillslope failures to near natural levels. Ultimate goals for wood and mass wasting can be expressed in this manner. However, to develop objectives that enable meaningful assessment of prescription effectiveness in a reasonable length of time, an estimate of rate of change towards the desired outcome is required.

Establishing goals in this manner requires an understanding of the range of conditions in largely unmanaged watersheds. Because unmanaged watersheds are often not available within the area where FFR prescriptions will be applied, determining the range of habitat types (e.g., pools), environmental attributes (e.g., abundance of large woody debris) or water quality attributes (e.g., water temperature) is often problematic. Two approaches have recently been applied to address this deficiency. Various modeling tools have been developed that predict likely ranges of conditions for some watershed attributes, like the distribution of forest stand ages or large wood in stream channels (Benda et al., 1998; Wimberley et al., 2000). These tools may prove useful for establishing desired ranges of outcomes for landscapes where no adequate reference information is available. Use of available historical information from a variety of sources also may prove useful in developing some understanding of the appropriate range of variability in certain watershed conditions. These historical reconstructions have been developed for several Puget Sound watersheds, including the Skagit (Beamer et al., 2000), Stillaguamish (Pess et al., 1999) and Nisqually (Collins and Montgomery, *in press*). In most cases, establishing desired ranges of conditions may best be accomplished by coupling empirical information from unmanaged watersheds with historical data and models that enable projections of possible past watershed conditions.

An understanding of the range of natural conditions a watershed is likely to exhibit through time provides a basis for establishing desired trends in monitored parameters in managed watersheds. For example, water temperatures recorded at multiple locations in an unmanaged basin might exhibit a frequency distribution as shown in Figure 4. If the distribution of water temperature in managed basins in the same ecoregion deviates significantly from the unmanaged basin, the desired outcome with the application of FFR would be a gradual shift in the frequency distribution towards that observed in the unmanaged basin. This approach acknowledges that a proportion of stream reaches in an unmanaged landscape will exhibit water temperatures different than those deemed desirable for certain species of interest. These deviations are usually caused by natural disturbances that remove streamside vegetation, such as fires or debris torrents. These periodic disturbances play a key role in maintaining long-term productivity of aquatic systems and are a vital process for maintaining watershed health (Reeves et al., 1995). Thus, warm water at some sites is not ecologically undesirable. Restoring an appropriate mix of water temperature conditions across a managed landscape would represent a management goal more realistic and biologically meaningful than a single, fixed water temperature value.

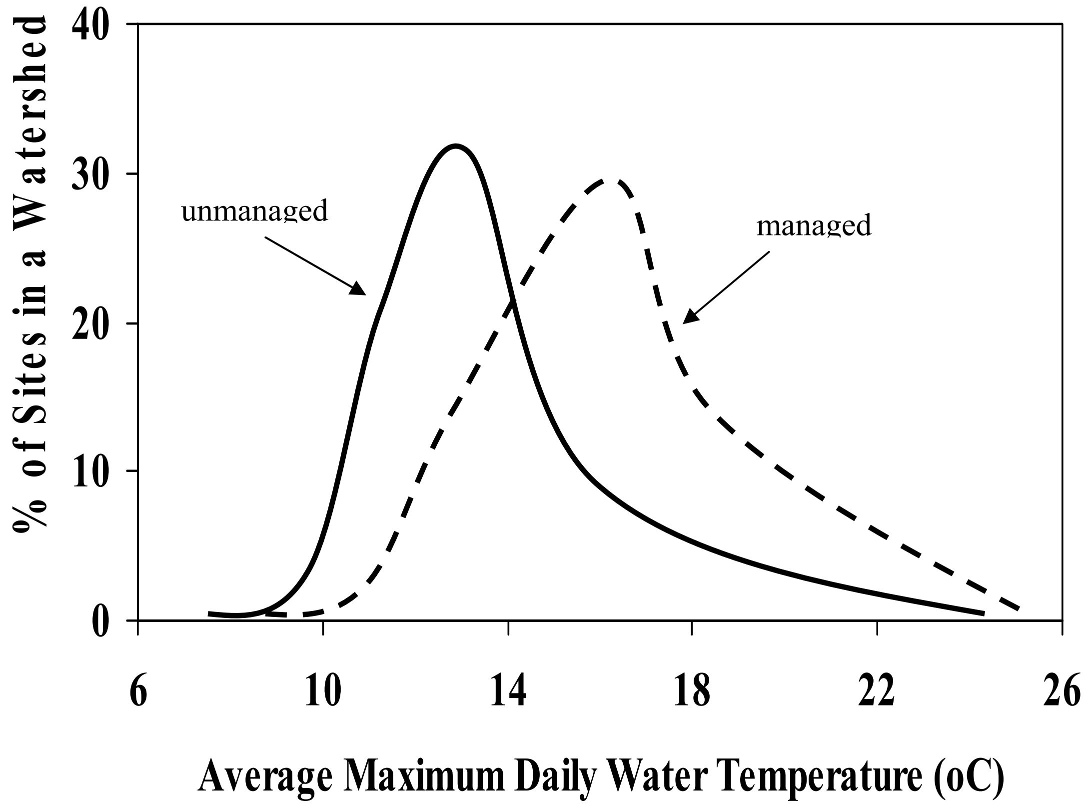

Figure 4. Theoretical frequency distribution of average maximum daily water temperature in an unmanaged and a managed watershed.

Estimating the rate at which the water temperature distribution would be expected to change with the application of the FFR prescriptions is possible using available data and models. As monitoring data is collected these relationships can be assessed and modified as appropriate. The prescriptions influencing water temperature (primarily vegetation retention for shade) would be considered effective if the distribution of temperatures in monitored watersheds moved towards the distribution seen in unmanaged systems at a rate expected based on the predicted growth of streamside vegetation and increase in shade over channels.

An detailed example of the application of this method of establishing performance criteria may be found in the Extensive Monitoring section of this document. This plan proposes to assess the efficacy of the FFR prescriptions related to water temperature by evaluating the rate at which the distribution of water temperatures at multiple sites managed under FFR approach the distribution of water temperatures obtained from multiple locations in unmanaged drainages. This approach acknowledges the fact that a range of water temperature would be expected under natural condition, owing to variability in site conditions and the effects of natural disturbances. The objective of the FFR prescriptions would be to move the distribution of temperatures from that currently exhibited in managed landscapes towards a distribution more representative of that seen in unmanaged systems. The ultimate extent to which the FFR distribution must correspond to the reference temperature distribution is a question that may be addressed in the intensively monitored watersheds, where the relationship between thermal conditions and the response of the biological resources can be evaluated. In the interim, the success of the FFR prescriptions can be judged the rate at which temperature distributions on managed lands move towards the reference distribution. The expected rate of change can be established using currently available models that predict shade with stand growth (Welty et al., 2002) coupled with empirical relationship between shade and water temperature derived from the data collected in the Extensive Monitoring effort.

Desired outcomes for various parameters can be articulated in this manner. Wood abundance, pool frequencies and other aquatic habitat attributes all exhibit spatial and temporal variation. This variation is caused by among-site differences in underlying physical features, disturbance history and dynamics of recovery. However, as most of these attributes will require a long period to achieve the desired endpoint, evaluation of the efficacy of FFR would best be judged by examining the direction and rate of movement towards the desired condition (Figure 3) rather than attainment of that desired condition.

The type of data needed to establish frequency distributions for wood in stream channels in unmanaged watersheds has been recently collected (Fox 2001). Wood abundance at sites selected randomly from areas of unlogged forest indicated a wide range in wood abundance in unmanaged landscapes (Figure 5). Even after accounting for effects of due to channel size and forest type, wood abundance varied about 10-fold. Therefore, establishing single-value, wood-abundance performance targets would be inappropriate. However, by measuring wood abundance, or some surrogate of wood abundance like riparian stand condition, at multiple sites in a managed landscape over time, the rate at which lands under FFR management approaches the distribution of wood at comparable reference sites can be determined. An expected rate of change in riparian conditions or wood abundance can be derived using one of the wood input models that have recently been developed (Welty et al., 2002; Beechie et al., 2001). Comparison of the measured riparian conditions with this expected condition could be used as a method of evaluating the FFR prescriptions for wood.

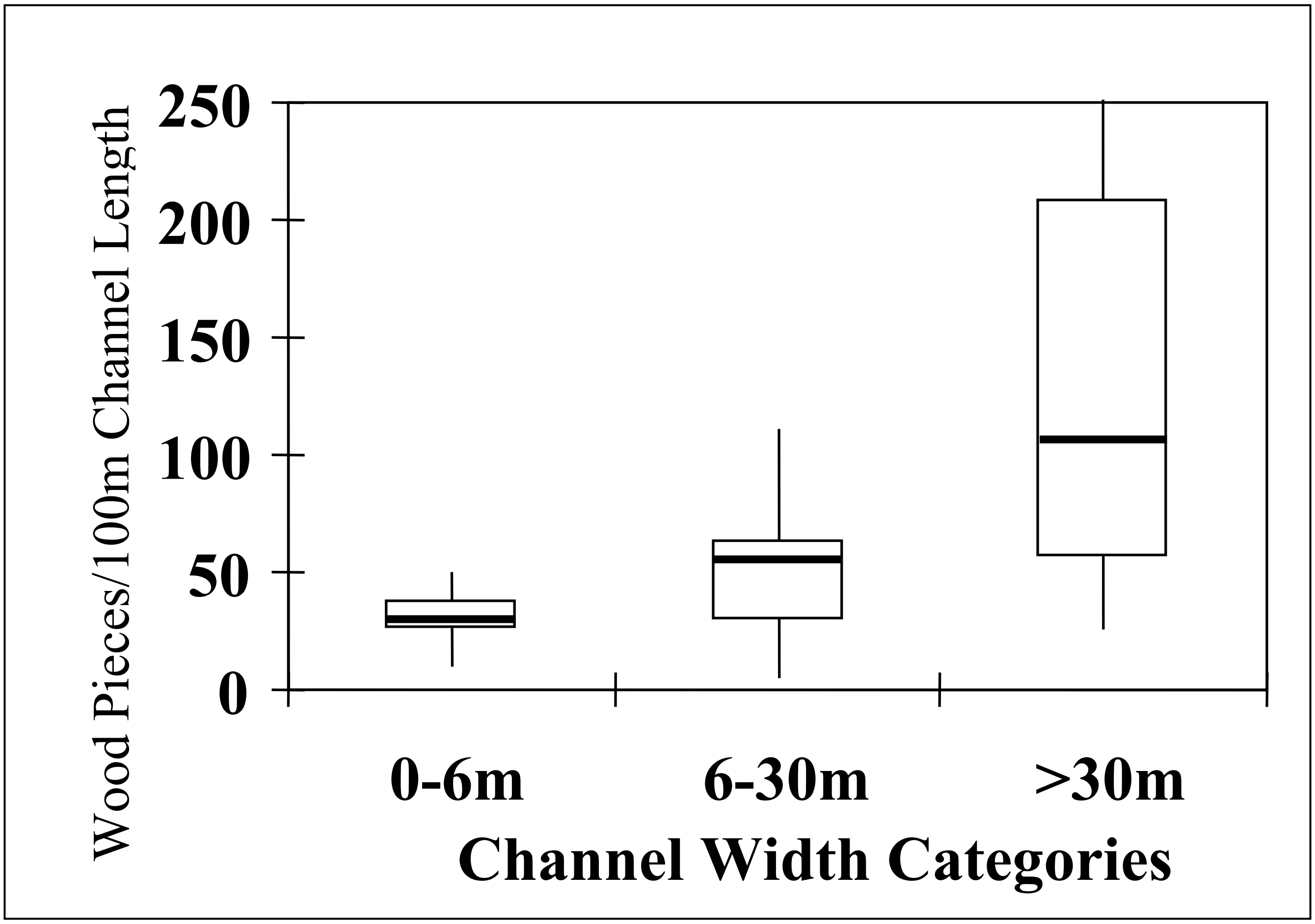

Figure 5: Distribution of wood abundance in stream reaches flowing through unmanaged forests in the western Washington Cascade Mountains. Values represented are the median abundance (dark line) the 25th and 75th percentiles of the distribution (box) and the 5th and 95th percentile of the distribution (whiskers). Data from Fox (2001).

A similar approach can be used to establish goals for biological attributes of monitored watersheds. As the biology of a stream reach is a direct reflection of the physical characteristics of the site, and these physical features change over space and time, biological characteristics also will display a range of conditions within a watershed. Thus, as with attributes like water temperature, biological parameters will display a characteristic frequency distribution of conditions across a watershed. For relatively immobile animals this distribution can be established by sampling representative locations across an unmanaged watershed, stratified for current physical condition. Thus, a desired condition for benthic invertebrates might be expressed as a range and distribution of some index value, diversity, taxonomic composition or abundance. A single condition or standard for invertebrates would be inappropriate, as natural variation in community characteristics among sites would be expected to occur (Reice, 1994). A comparable approach might be applied to amphibians.

The high mobility of fishes, especially anadromous fishes, and the great degree of variation in abundance over space and time complicates the process of establishing meaningful standards for these animals. Some of this variation is not related directly to freshwater habitat quality but to the variable effects of weather and flow conditions on survival and fish production or due to factors impacting the fish in the marine environment, which affects the number of adults returning to spawn. As this variability is not a direct product of the condition of the freshwater habitat, it is difficult to account for in attempting to relate fish abundance to habitat condition.

In fact, fish abundance may not be the most appropriate attribute to use in assessing the efficacy of a set of land management prescriptions. The large interannual variation in fish abundance means that a response in population size to a FFR management action would not be detectable unless the response were extremely large or data were collected over a period of decades (Bisson et al., 1997; Ham and Pearsons, 2000). However, other metrics of fish community response have been proposed over the last several years, some of which show promise for detecting modest responses over realistic time frames. Alterations in the production of smolts per spawning female salmon and changes in the spatial distribution of salmon abundance across a watershed have both been proposed as measures that would enable fish population performance to be associated with freshwater habitat quality, and therefore, with land management actions (Botkin et al., 2000; Pess et al., 2002).

It is not possible to use a range of conditions in an unmanaged watershed to establish ultimate goals for some environmental attributes influenced by forestry. For example, generation of road surface sediment in an unmanaged watershed is likely to be very small (or non-existent) due to low (or no) road frequency and use. Even with aggressive management of road runoff in managed watersheds, it is not likely that total elimination of input of fine sediment can be achieved (Duncan et al., 1987). However, use of a trend in condition can still be applied to these watershed attributes. The desired rate of change can be predicated on the rate at which problem areas are addressed and the predicted reduction in sediment delivery to stream which results. The ultimate desired endpoint for these types of management-associated parameters can be established by relating level of the attribute with response of key biological characteristics of the system. This endpoint can be determined by research in the intensively monitored watersheds, where sufficient scientific resources and infrastructure should be available to address these complex questions.

Regardless of the parameters being evaluated in a monitoring program for forest practices, interpretation of the results must acknowledge the natural variability in conditions across landscapes. Development of more refined desired future resource conditions for forested watersheds should be viewed as a component of the effectiveness monitoring effort under FFR. The types of measurements required to evaluate the effectiveness of the FFR prescriptions can yield considerable information about the relationship between watershed condition, aquatic habitat and water quality and resulting biological response. Replacing inflexible standards with more ecologically based performance measures that reflect the resilience, complexity, and adaptability of aquatic ecosystems will be challenging and contentious. Nonetheless, the adaptive management component of FFR will be of limited utility unless this step is taken. Desired outcomes of FFR must be articulated in a manner relevant to the resources being protected or restored in order to meet the dual goals of continued production of wood and improvement in the condition and productivity of aquatic systems in managed landscapes.

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Monitoring Design

The working assumption of the FFR is that the proper implementation of the appropriate prescriptions will attain the Performance Targets. Attainment of the Performance Targets will meet the Resource Objectives which will result in meeting the Overall Performance Goals of FFR listed earlier. FFR recognized that ongoing research and evaluation was necessary to validate this assumption and to better understand the connections between forest management and the Resource Objectives.

Because of the similarity of the questions across monitoring scales, some indicators may be monitored at all scales. However, at some scales certain indicators either cannot be cost effectively monitored or do not provide meaningful information. For example, continuous flow measurement would be prohibitively expensive at a state-wide scale, while comparing the number of fish in a stream reach before and after a riparian prescription is applied would mean little biologically. Instead the MDT has tried to tailor the indicators monitored to the scale and the question addressed. In some cases, inferences can be made about the indicator of interest by monitoring an easily measured surrogate indicator (Table 1). For example, fine sediment from roads may be estimated indirectly at the extensive scale using models validated through direct measurements done at the Prescription and Intensive scales. Likewise, LWD and litterfall would be inferred from riparian stand condition. Table 1 is an overview of the resource conditions and input processes from Schedule L-1 (FFR 1999) that were reviewed as potential monitoring indicators. In general, only inexpensive, easy-to-measure indicators are measured directly in Extensive Monitoring. Others are inferred and will require some validation of the relationship. More costly and difficult-to-measure indicators can be included in the Prescription and Intensive Monitoring because of the smaller spatial scale.

Table 1. Overview of the indicators measured at each monitoring scale. Indicators are measured directly where necessary and feasible. Extensive Monitoring relies heavily on surrogate indicators. The relationship with surrogate indicators must be validated via Intensive Monitoring. (D = direct measure; I = indirect or surrogate measure or indicator, such as modeled fine sediment erosion from roads).

Resource and Input Variables	Monitoring Elements		
	Extensive Status and Trend Monitoring	Intensive Watershed Scale Monitoring	Prescription Monitoring
Biota			
Fish		D	
Amphibians	D	D	D
Macroinvertebrates		D	
Riparian			
Stand condition	D	D	D
LWD	I	D	D
Shade/Temperature	D	D	D
Litterfall	I	D	I
Sediment from harvest streambank disturbance		I	I
Unstable Slopes			
Sediment from mass wasting, Harvest			I
Sediment from mass wasting, new roads	I	I	I
Sediment from mass wasting, old roads			D
Roads			
Fine sediment from surface erosion	I	D	D
Hydrologic connectivity	I	D	
Fish passage	I	D	D
Harvest			
Peak flow (bed scour)		D	
Wetlands			
Forested wetland regeneration			D
Hydrologic function			D
Wetland management zones			D
Forest Chemicals			
Chemical inputs			D

Prescription Monitoring

Prescription monitoring consists of a series of projects to evaluate the effects of individual FFR prescriptions and/or alternative management treatments on input processes (e.g., heat input) and resource conditions (e.g., water temperature). The purpose of this monitoring is to evaluate the effectiveness of individual FFR prescriptions under a range of different physiographic conditions, identify sensitive areas where specific prescriptions are relatively ineffective, and evaluate alternative treatments for meeting resource objective.

Prescription monitoring will combine passive monitoring elements to evaluate the effect of existing prescriptions, as well as an active monitoring approach that compares the effectiveness of alternative treatments in some situations. Passive prescription monitoring is the process of measuring input process or resource condition without necessarily trying to understand how or why those conditions change, although causative agents are often assumed based on prior knowledge. Information from passive monitoring will be used to evaluate whether the prescriptions are meeting some Performance Target. Information from this passive type of monitoring may not offer insights into how to change prescriptions to better meet Performance Targets.

Active prescription monitoring typically takes the form of comparisons between multiple treatments (often phrased as control versus treatment(s) experiments). Ideally, all factors that can affect the response variable of interest (e.g., stream temperature) are kept constant except the factor for which the monitoring is designed to test (e.g., shade provided by the riparian forest). By controlling for other possible causes while manipulating a single factor, one can often infer the nature of cause-and-effect relationships, even if all the mechanisms that govern that relationship are not characterized. Often active monitoring will allow the development of empirical relationships between a cause and an effect that can be use by managers to meet certain performance targets. The relationship depicted between shade and stream temperature in the monograph is a good example of an empirical relationship that could arise from active prescription monitoring.

Typically, prescription monitoring projects will occur at a site scale. Some prescription monitoring will address cause-and-effect relationships (e.g., how specific road building practices results in fine sediment delivery to streams). Others will be targeted at understanding how specific management practices can be improved from a logistic perspective (e.g., practice A is as effective as practice B in providing shade but is less costly). Information regarding specific prescription monitoring studies is available from CMER's Science Advisory Groups (SAGs), which design and oversee the implementation of the studies.

Prescription monitoring will consist of active manipulation and monitoring to examine the effectiveness of specific treatments and alternative treatments. These projects will examine multiple effects where feasible but generally will have a narrow focus. Individual monitoring projects will be prioritized and developed within the SAGs. An example is the influence of riparian harvest prescriptions on Type N stream temperature. Each experimental design and monitoring approach may vary substantially among effects examined and the prescriptions being monitored.

The MDT recommends paired treatment and control sites, and/or pre- and post-treatment study designs for this monitoring component. Stratification by geographic area or other appropriate physical variables should be considered since it may account for variability not associated with the prescription. Monitoring projects developed for this component should have estimated minimum detectable differences appropriate for the input process being monitored. Sample size analysis, using the appropriate power and levels of risk for type I and II statistical error, should be completed prior to implementing the treatment. These analyses can often be completed using existing data. If representative data are not available to complete these analyses, preliminary data should be collected to allow these analyses to be completed. In most cases the data will focus on physical stream input processes similar to those monitored at the intensive and extensive scale. However, additional, more specific monitoring data will likely need to be collected to account for appropriate covariates. Biological parameters will generally not be measured during prescription monitoring activities. Biological data are generally difficult to interpret at finer monitoring scales.

Prescription Monitoring Projects under Consideration by CMER

Prescription monitoring projects are listed below. These projects are designed by carried out by the Scientific Advisory Groups (SAGs) that report to the Cooperative Monitoring, Evaluation and Research (CMER) Committee. These projects are in various states of completion, from initial scoping to study design peer-review to the pilot study phase. A much more thorough study description in the form of a CMER work-plan will be available in the spring 2002.

Riparian Management

Fish- and Nonfish-bearing Perennial Stream Prescription Effectiveness

This study will help define areas of particular resource sensitivity to forest management and measure the effects of riparian prescriptions on: stream water temperature, large woody debris recruitment potential and recruitment rate, habitat formed by LWD in- and near-streams, and amphibian responses (in and near-stream) to forest management. This group of studies may ultimately include other input processes (e.g., bank erosion) or the expression of those processes on aquatic organisms and their habitat.

Bull Trout Overlay

This study will test the effectiveness of the "all available shade" rule versus standard forest and fish riparian management prescriptions in eastern Washington for maintaining or restoring water temperatures necessary for bull trout. This study will use a treatment/control experimental design.

Hardwood Conversion

This project will determine the effectiveness of hardwood conversion rules in meeting short-term water temperature requirements, and long-term DFC and LWD requirements. Hardwood conversion is the process of replacing stands whose canopy is dominated by hardwoods to stands dominated by conifers. This study will use a treatment/control experimental design.

Amphibian Use of Seeps

This study will test the effectiveness of headwater (nonfish bearing perennial) stream buffers for protecting the viability of 6 species (now 7 species as tailed frog was split into two species) of stream-associated amphibians. Initial phases of the study will look at amphibian use of seeps versus other aquatic habitats in headwater basins to determine: 1) the general value of seeps to amphibians, 2) if seeps act as salamander breeding sites, 3) the value of seeps to amphibians as a function of seep density and location. Later phases of the study will determine local extinction and recolonization events at the harvest unit scale (Stream Type N scale).

Forest Roads

Road Maintenance and Abandonment Plans (RMAPS)

The purpose of this study is to test the effectiveness of Road Maintenance and Abandonment Plans (RMAPs) to reduce road generated fine sediment and runoff, and to reduce the incidence of mass wasting associated with roads. This study will evaluate RMAPs at the basin scale and will test effectiveness in different physiographic regions and landowner planning areas.

Effectiveness of Specific Road Best Management Practices (BMPs)

This study will test the effectiveness of site scale BMPs (e.g., culvert spacing) at reducing the delivery of road generated fine sediment and water to streams. The study will test the effectiveness of current rules as well as alternative prescriptions using a treatment/control experimental design.

Fish and Amphibian Passage

This study will investigate resident salmonid movement behavior in small streams and determine how culverts affect fish movement in a variety of situations. The ultimate goal of this study is to provide a means to rate the significance of a given culvert in affecting fish movement in order to prioritize the order in which culvert repairs will be conducted. The specific objectives are 1) investigate how stream crossing structures affect the volitional upstream movement of fish and amphibians, and 2) evaluate the association among structural and hydraulic features of culverts, barrier status (passable/impassable), and fish movement.

Harvest Related Prescriptions

Mass Wasting

Specific prescriptions governing forest practices for mass wasting are not defined at the present time, therefore an effectiveness study will be deferred until the prescription are identified.

Initially research is focused on developing landslide screening tools, protocols for identifying unstable landforms, and measurable metrics for classifying landslides. Some initial components of these studies have been completed by the DNR and are in technical review.

Streambank/Surface Erosion

This study is focused on evaluating stream bank erosion and surface erosion associated with timber yarding corridors, and patch buffers in perennial nonfish-bearing streams (Np) in eastern and western Washington. This study will be a component of the Type N/F (i.e., fish/nonfish) Stream Prescription Effectiveness study (described above)

Runoff in the Rain on Snow Zone

Objectives: This study will test the effectiveness of rain-on-snow prescriptions in meeting peakflow targets.

Forest Regeneration in Wetlands

This project will evaluate the effectiveness of forest regeneration in harvested forest wetlands. Regeneration will be compared to surrounding non-wetland sites to determine if wetlands regenerate more slowly than upland forest, and if wetlands have different forest successional dynamics than adjacent upland forests. A retrospective analysis of forest regeneration using historical aerial photos will form the basis of this study.

Groundwater Conceptual Models

This study will include the: (1) development of a conceptual model(s) to evaluate cause-and-effect relationships between forest practices and groundwater temperatures; (2) identification of hypotheses about forest practice influences on groundwater temperatures at site and watershed scales, based on the information learned from the conceptual model(s); (3) development of experimental designs for testing the priority hypotheses; and (4) Develop cost estimates for the experimental designs.

Habitat Conservation Plan (section 4(d)) Population Response and Effectiveness Monitoring

These studies would provide baseline populations for bull trout, against which the effectiveness of the Forest and Fish Report can be measured. The population response of bull trout in typical watersheds (i.e., intensively monitored watershed) and relate it to habitat response across the broader array of watersheds (i.e., extensively monitored watersheds). CMER will initiate projects to address the following needs: Baseline Population Data to determine and track amount of incidental take authorized. Population abundance would be monitored in the Intensively Monitored Watersheds identified by the Monitoring Design Team.

Intensive monitoring (discussed below) will address the issues of cumulative effects of combinations of prescriptions across larger spatial scales. Answers to the above questions will be valuable for understanding the status and trend data obtained from the extensive monitoring component. They will also be valuable for understanding observations on the physical conditions and the biological communities from the intensively monitored watersheds.

Extensive Monitoring

Extensive Monitoring is a population-scale assessment of the effectiveness of FFR rules in attaining specific Performance Targets across FFR lands. Where Prescription Monitoring will estimate the effects of a specific prescription at that site, Extensive Monitoring estimates the distribution of conditions across the landscape regardless of management history as FFR rules are applied and represents the ultimate test of whether FFR rules are effective in meeting the conditions needed to protect salmon and other protected species.

Not all Performance Targets in Schedule L-1 can effectively be monitored. Some, such as those for riparian shade based upon “all available shade”, are narratives intended to guide implementation rather than quantitative targets. Some, like the target for Hydrology, “Increases in 2-year peak flows related to forest management (roads and harvest) are ≤20%” are possible to monitor but would require a huge investment in time and resources at each site to separate the natural variability from that due to forest management. Other Performance Targets are based on a comparison to ‘background’ or the ‘potential’ of specific conditions and would require substantial research to estimate these conditions (Table 2). The MDT recommends monitoring several well-defined Performance Targets that can be monitored cost-effectively. Some Performance Targets should be validated through Intensive Monitoring (described below) to better define the target conditions and to investigate whether indirect measures of correlated surrogate indicators or remotely-gathered data would suffice. The adaptive management framework provides a means to reassess monitoring needs over time as more information is developed and as technology improves.

Explicit Performance Targets were listed in FFR Schedule L-1 in five resource categories. Although not listed in Schedule L-1, the Performance Targets for fish passage, implied by the Road Maintenance and Abandonment Plans (FFR, 1999), and amphibian viability are included here under biota.

Table 2. FFR performance targets evaluated for extensive monitoring.

Resource Category/indicator	Monitored	Why?
Heat-Water temperature		
Stream temperature	Y	Required for CWA
Shade	Y	Covariate for stream temperature
LWD-Organic inputs		
Riparian Condition	Y	Compare to DFC
In-stream LWD	N	Costly, target based on undefined recruitment potential of DFC, inferred from riparian stand
Litterfall	N	Target based on undefined recruitment potential, inferred from riparian stand
Sediment		
Mass Wasting	-	Being evaluated
Roads	-	Monitoring plan in progress.
Streambank disturbance	N	Better studied on Type N prescription monitoring sites or through implementation monitoring.
Hydrology		
Road run-off	-	Monitoring plan in progress.
Peak stream flows	N	Very high per site costs and extremely long time frame needed.
Wetlands	N	Requires some research into forested wetlands to describe hydrologic functions.
Chemical inputs		
Entry to water	N	Better addressed at prescription scale
Entry to RMZs	N	Better addressed at prescription scale
Biota		
Fish Passage	Y	Measures progress toward Performance Target
Amphibian presence	Y	Addresses landscape performance target of maintaining extant populations through time

Given the tradeoffs among between the resolution of the data and cost, the MDT recommends extensive monitoring only on the most important indicators needed by the regulatory agencies to determine if progress is consistent with expectations. The team also limited their extensive indicators to those that could be collected relatively easily (by remote means in some cases), and with relatively low sampling error. Extensive monitoring indicators must provide useful information to judge the success of the FFR despite the inherent variability associated with those indicators. This variability is the result of the complex natural history, including recurring disturbance that is typical of riverine systems (Pess et al., *in press*).

The common feature of the four Extensive monitoring elements below is scale (Table 3). All will produce an estimate of status and trends at a statewide scale on FFR lands. The monitoring plans do not, by design, share sites or monitoring indicators. Data collection in each element is tailored to the specific resource conditions. The indicators are similar to those monitored in the Intensive and Prescription scale monitoring but are measured at different spatial and temporal intensities. Information flow among the elements of extensive monitoring and among the three scales of monitoring is critical to the interpretation of the monitoring data and feeding the adaptive management loop.

Extensive monitoring will measure the success of the FFR in meeting performance targets that were developed in FFR or that will be developed as part of the adaptive management program (see discussion on performance targets). In some cases, extensive monitoring will provide data to help establish or validate performance targets and resource objectives. This could be accomplished by including extensive monitoring sites in relatively undisturbed areas (reference sites) that could serve as reasonable estimates of potential conditions.

Table 3. Individual elements of the extensive monitoring network.
Each element is an independent monitoring effort.

Element	Stratification	Indicators
Riparian	East vs west side	Stream temperature, riparian shade, riparian stand condition
Amphibian	Level III ecoregions	(in progress)
Fish passage	None	WDFW fish passage protocol
Roads		(in progress)
Mass wasting		(in progress)

No attempt will be made to monitor specific treatments or their separate effects, although *post hoc* analysis may begin to reveal important patterns in subsets of the data. The purpose of the *post hoc* analyses is to identify associations between resource conditions and the stratum, site location, or other site-specific features. For example, is there a distinct set of site conditions where high stream temperatures are more likely to occur or are fish passage barriers more common in a particular geologic stratum? These associations could be useful in adaptive management by guiding further research, directing resources to areas of greater uncertainty, and in policy decisions.

The fundamental questions addressed in extensive monitoring are:

- Is the proportion of culverts that provide fish passage increasing through time?
- Are fish-bearing stream temperatures decreasing and shade to fish bearing streams increasing in ways that are consistent with our expectations?
- Do the data provide the assurance of regulatory compliance needed for the Clean Water Act?

Extensive Riparian Monitoring

Extensive Riparian Monitoring will evaluate the response of key aquatic and riparian indicators to the implementation of the FFR across the entire range of environmental conditions on FFR lands across the state. This is a population-scale estimate of conditions and sites will be selected without regard to current conditions or management history in order to obtain an unbiased estimate.

A number of indicators (Table 4) were considered for monitoring based on:

- The efficacy of the indicator in evaluating the effectiveness of FFR in complying with the Clean Water Act (CWA), the Endangered Species Act (ESA), or targets set for other covered biota.
- The appropriateness of the indicator as a measure of riparian or aquatic habitat.
- The statistical power to detect a meaningful change in the indicator over an appropriate time span.
- The cost of data collection, analysis, interpretation and reporting.

Table 4. Indicators considered for inclusion in extensive riparian monitoring. Indicators in bold type were selected for monitoring. Stream temperature and riparian stand condition are the actual indicators of interest. Others will be treated as covariates to help interpret the data.

Indicator	Included (Yes/No)
Diel water temperature	Y
Diel air temperature	Y
Groundwater temperature	N
Riparian stand characteristics	Y
Riparian shade	Y
Radiation input	N
Stream flow	N
Topographic features (elevation, aspect)	Y
Channel characteristics	Y
LWD	N
Aquatic biota (tailed frog)	Y
Basin land cover	Y
Prescription applied	N

Stream temperature and riparian stand condition were chosen because FFR set Performance Targets for each. Air temperature, riparian shade, topographic features, instream channel characteristics and basin land cover were included because they can be important explanatory variables (covariates) in the analysis of the stream temperature. Stream temperature is directly addressed in the CWA and is a component of aquatic habitat. The cost of data collection is quite low (using *in situ* temperature loggers) and the statistical power to detect changes is high when several, easy-to-measure covariates are included. Riparian stand condition is a direct measure of riparian habitat and may function as a covariate in the stream temperature analysis. In addition, riparian stand condition may feed into existing models that can predict the trajectory of riparian stand growth and yield, riparian shade, and LWD input. Tailed frog presence/absence in a Type Np Basin was chosen because FFR amphibian performance target is related to the persistence of tailed frogs across Washington State through time. Presence/absence sampling will be used to assess changes in distribution in tailed frogs across many type Np subbasins   Some variables were excluded because of cost (stream flow, LWD, radiation input) or difficulty in relating the measurements to the goals at this scale (other aquatic biota, LWD, groundwater temperature, prescription applied).

To determine the effectiveness of FFR in meeting the Overall Goal to "Meet or exceed water quality standards" (temperature is the primary issue) will require (1) an unbiased estimate of the current conditions (reflection of past and current rules), and (2) an estimate of the trends occurring over time as the FFR rules are implemented.

Extensive Riparian Monitoring will address these basic issues:

1. Status and trends in stream temperature and riparian stand condition.
2. Conditions, natural and man-made, associated with high stream temperatures.
3. Spatial distribution of tailed frogs in Type Np streams.

Monitoring Design

Extensive riparian monitoring uses the temperature monitoring site (stream reach) as the basic unit of evaluation because:

- Compliance with state water quality standards is based on this scale.
- Implementation of FFR riparian strategies will be done on a harvest unit (tens to hundreds of meters) basis.
- Changes in temperature are easily detected at this scale.
- The data from individual sites may be rolled up into an estimate of conditions on a larger geographic scale.
- The entire landbase will continue to be under active forest management. The current condition varies markedly with stand age and past management and some leeway exists in how the riparian strategy is implemented at harvest. The end result is that there is considerable variability in current conditions and a larger number of sampling units, at the expense of unit size, should provide a better estimate of the chosen indicators.

Stratification, at least at a coarse scale, is necessary because of the different riparian prescriptions for eastern vs. western Washington forests. In addition, it is likely that the indicator variables will respond differently to FFR because of natural (e.g., precipitation, climate, geology) and management-related (how FFR riparian prescriptions are implemented) factors. Initially, the MDT has chosen to focus on west-side forests and to not stratify. As data are collected they will be evaluated for distinct differences among Level III ecoregions (Omernick, 1995) after variability due to elevation, basin size, latitude, shade, air temperature, etc is removed. If indicated, additional sites may be selected in targeted strata. The major impediment for developing an eastside strategy was that land ownership information has not been systematically compiled. Maps of individual ownerships exist for the large landowners, but even these are not readily available.

Temperature Monitoring

The EMAP probability-based sampling procedure will be used to select the sites for temperature monitoring (Overton et al., 1990). The procedure lays a GIS grid over digital line graphs of the stream network. Stream segments within a grid cell are clipped and linked to form a line then linked with streams from nearby cells to from one continuous line. A start point is randomly selected on the line, then additional points are selected at set intervals. The points are then projected on the stream network coverage. This produces a spatially-balanced random sample and avoids the clumping that occurs with simple random selection. Where the attribute being measured is uniformly distributed across the geographic area being sampled, this approach produces similar variance estimates as a simple random selection. However, where the attribute is correlated with spatial features (e.g., elevation, latitude, ecoregion), the variance estimates will be substantially lower (Overton and McDonald, 1998).

Fish-bearing and nonfish-bearing streams will be treated as separate populations and a sample will be drawn from each. Until the stream typing model is complete, the current stream typing system will be used to differentiate Type N and Type F streams. Type 1-3 streams will be assumed to be Type F. Type 4 and 5 streams will be assumed to be Type N streams. Sites on Type 4-5 streams with a basin size less than the default basin size will be assumed to be Type Ns and not included in the sample. If a field visit indicates that the classification is obviously incorrect, then the field-based judge will be used. When the stream typing model is complete, the sampling frame may be adjusted as indicated.

Other variables, which can influence water temperature or should respond to FFR, including riparian shade, channel geometry, site coordinates, elevation, aspect, basin area, distance to watershed divide, and air temperature (Table 5) will be measured at each temperature monitoring site (Schuett-Hames et al., 1996). Riparian shade and channel geometry will be measured at the temperature monitor and proceeding upstream at 50m intervals for 300m. The air temperature monitor will be located within the riparian buffer, where possible, and shielded from direct sun. Site coordinates, elevation, and aspect will be measured on site while basin area and distance to divide will be estimated form GIS coverage. On non-fish bearing streams, the proportion of the basin above the monitor in early, mature, and old growth forest will be estimated from the most recent digital orthophotos.

A tradeoff exists between estimating status and trend detection. A better status estimate may be obtained by sampling more sites while trend detection is enhanced by repeated visits to the same sites. Initially, a simple rotating panel design was chosen (Rao and Graham, 1964; Skalski, 1990) where sites will be resampled at 5-year intervals. If 50 sites can be measured per year, then over the rotation period 250 sites can be measured for a status estimate. A five year rotation was chosen as a reasonable time to expect shade to recover after harvest on Westside Type N streams and changes would be unlikely to occur with much shorter intervals between visits.

Riparian Stand Conditions

There is considerable uncertainty about the current riparian stand condition, especially the proportion of hardwood dominated riparian stands, and whether these are on the DFC trajectory. The objective of monitoring stand condition is to estimate the proportion of riparian stands meeting the DFC basal area targets. Areas of uniform stand characteristics within the riparian buffer will be delineated and estimates of basal area and species composition will be derived using low-level (1:2000) aerial photography. The delineated areas can be mapped onto the 1:24k hydrology layer for a more detailed analysis of stand condition by riparian buffer zone. These analyses will provide a more precise estimate of the current riparian condition with respect to DFC and can be used to assess the need to convert hardwood stands to conifer.

The question of sample size is dependent upon the variability across the landscape and the variability at a given site. Total costs are dependent upon the number of sites. Generally, it is more cost efficient to improve the estimate at a given site, in this case by evaluating a longer stream reach, before moving to the next site. Developing specific monitoring protocols will require existing riparian stand condition data to estimate the length of the stream to measure that will accurately characterize a site and an evaluation of the photo scale required. These will be done as this monitoring report is periodically updated.

Table 5. Indicators measured for extensive riparian monitoring.

Component	Indicator	Data collection	Frequency
Water Temperature	Stream temp, air temp, riparian shade basin seral stage on Type N streams	Temperature-*in situ* thermistors Shade-densiometer Seral stage-digital orthophotos	Temperature- diel June through Sept at 5 year intervals Riparian shade-5 year interval
Channel geometry	Channel geometry and gradient	Instream measurements	5-year interval
Site location	Latitude, longitude, elevation, aspect	GPS system, on-site, maps	Once
Riparian stand	Species composition, basal area	Estimate from air photos	10-year interval

Quality Assurance

Measures to insure consistent data quality will be implemented throughout the data collection process. Temperature monitors will be compared to a National Bureau of Standards thermometer at least one time per year across a range of water temperatures from 0 – 20+ degrees C. Monitors outside the manufacturer's specified tolerance will be replaced. Riparian shade, and in channel measurements will be compared to repeated measures made by a different field crew at 10% of the monitoring sites and the data evaluated for adequacy. The accuracy of GPS latitude and longitude measurements will be assessed by taking measurements at locations with known coordinates. All air photo derived measurements will be ground-truthed to estimate the accuracy of assessing riparian stand categories.

Data Analysis

There will be no active effort to apply specific treatments and isolate the effects. Instead, the entire suite of FFR prescriptions and its application across the landscape is the treatment. The impacts will be assessed as FFR is implemented. In addition to monitoring stream temperature, other variables (Table 4) will be recorded in order to link the observed trends to likely causal factors and to differentiate natural variability from management effects (McDonald et al., 1991). For example, in addition to estimating the proportion of stream reaches meeting a temperature criterion, the conditions under which the standards are (or are not) being met should be identified. Perhaps temperature standards are not met in low elevation streams, in streams with low riparian shade, only during unusually hot summers, or some combination of conditions. This information will allow us to include these factors in estimating the status and will also feed back into the adaptive management system to direct research efforts or policy action. In order to accomplish this, analyses will be done at the temperature monitoring site scale and at the stratum scale (Table 6).

Table 6. Spatial scales for data analysis and potential variables analyzed at each scale.

Scale	Variables
Reach	Stream temperature-daily max, 7-day average maximum, daily min, daily mean,
Stratum	Stream temperature- Max summer, mean daily max, max 7-day average maximum Riparian conditions-basal area

Site-Scale Analysis

Stream temperature, from which several variables may be derived, is the only parameter analyzed at a site scale (Table 6). For each variable, the critical question is 'After accounting for differences in air temperature between years, has the stream temperature changed?' Further analysis of the estimated site-specific changes in stream temperature may help to differentiate between the effects of interannual differences in weather and changes due to FFR.

To illustrate, maximum daily temperature was used, but a similar analysis could be done for other temperature-derived variables. The regression model below can control for air temperature and account for typical seasonal variation in water temperature unrelated to management.

$$T_{water} = \beta_0 + \beta_1 * T_{air} + \beta_2 * \sin(time) + \beta_3 * \cos(time) \qquad (1)$$

Where,

T_{water} = maximum daily temperature at the treatment site,

T_{air}= maximum daily air temperature at the control site,

Sin(time) and cos(time)=terms to account for seasonal variation in water temperature,

β_0, β_1, β_2, and β_3 are the regression coefficients.

Serially collected (time series) data are often autocorrelated, where a significant correlation exists between consecutive measurements. This violates the assumption of independent observations and will overstate the effective sample size. In general, autocorrelation can be avoided by:

- Including terms to account for the seasonality of the data.
- Increasing the interval between consecutive measurements (Helsel and Hirsch 1992).
- Including a lag 1 autocorrelation term in the regression (Hostetler, 1991).

Data from small, perennial streams in a managed forest in western Washington state (Weyerhaeuser) showed that a combination of seasonal functions and a reduction in the sampling frequency to twice weekly reduced autocorrelation from $r > 0.5$ ($P < 0.05$) to $r < 0.1$ ($P > 0.05$). Inclusion of a lag 1 autocorrelation term with daily measurements has also been used with satisfactory results (Hostetler, 1991). When data are available, the methods will be tested to select an optimum protocol for data analysis for select variables.

Changes in stream temperature over time will be assessed by comparing the slope and y-intercept of the water temperature vs. air temperature regression line for year *n* vs. *n+5*. In streams with elevated water temperature due to a lack of riparian shade, the slope and/or the y-intercept of the water temperature vs. air temperature curve should decrease over time as the riparian stand recovers. The null hypotheses are:

$H_{0,intercept}$: $\beta_{0,n+5} = \beta_{0,n}$

$H_{0,slope}$: $\beta_{1,n+5} = \beta_{1,n}$

A power analysis was done using data from seven small perennial western Washington streams (data from Weyerhaeuser) to estimate the minimum detectable change in temperature between years at a given site. The linear model described above with twice per week sampling was used and the variance of the regression residuals was calculated for each year at seven stream sites (two years of data from each =14 sets of data). The minimum detectable difference was estimated for each data set as:

$$\Delta T = \sqrt{(2s^2 / n)}(t_{1-\alpha/2} + t_{1-\beta}) \qquad (2)$$

Where ΔT = detectable change,

s^2= variance of regression residuals for each dataset,

n= sample size (based on two samples per week, n ranged from 19-24),

α= 0.05,
β= 0.05.

Estimates of ΔT ranged from 0.2 to 0.8 C, with median and mean values of 0.3 and 0.4 C, respectively. This is near the accuracy (0.2 C) of the temperature loggers (Onset, 1999), which should be adequate for this work.

Stratum-Scale

Estimates of the proportion of streams meeting water quality standards can be illustrated using the frequency distribution of stream temperature by stratum (Figure 6a). The assumption is that FFR will reduce stream temperature by increasing riparian shade, so that a downward shift in the distribution of temperatures over time (Figure 6b-d) should occur in conjunction with a shift toward more riparian shade as the stands mature (Figure 7a-d). However, this does not account for the natural variability in stream temperature nor for interannual differences in stream temperature due to differences in air temperature. Stream temperature is not impacted to the same degree in all streams nor will all streams respond similarly to FFR. In order to evaluate the effectiveness of FFR the effects of site location (spatial variability) and air temperature (interannual variability) must be accounted for before examining the residual variability for changes.

A simple empirical model relating stream temperature to a set of site condition variables will be estimated to remove the variability of due to air temperature, elevation, latitude, stratum, basin area, stream size, aspect, and other variables that causing the natural variability in stream temperature. The model could be developed using the current conditions as the baseline from which to gauge changes or it could be based on data from reference sites (described below) representing a similar landscape not subject to intensive timber harvest. Regardless, the model will remove the influence of spatial variability and interannual variability so that changes in stream temperature due to shade can be isolated and evaluated.

Changes in stream temperature will be assessed by comparing difference between the observed and predicted temperatures (model residuals) over time. A paired t-test could be used to compare the distribution of residuals between two sampling periods. However, because of the expected variability in response among sites (more impacted sites are more likely to respond than are relatively unimpacted sites), it may be more informative to examine the data to identify the conditions where FFR is not successful in meeting the performance criteria.

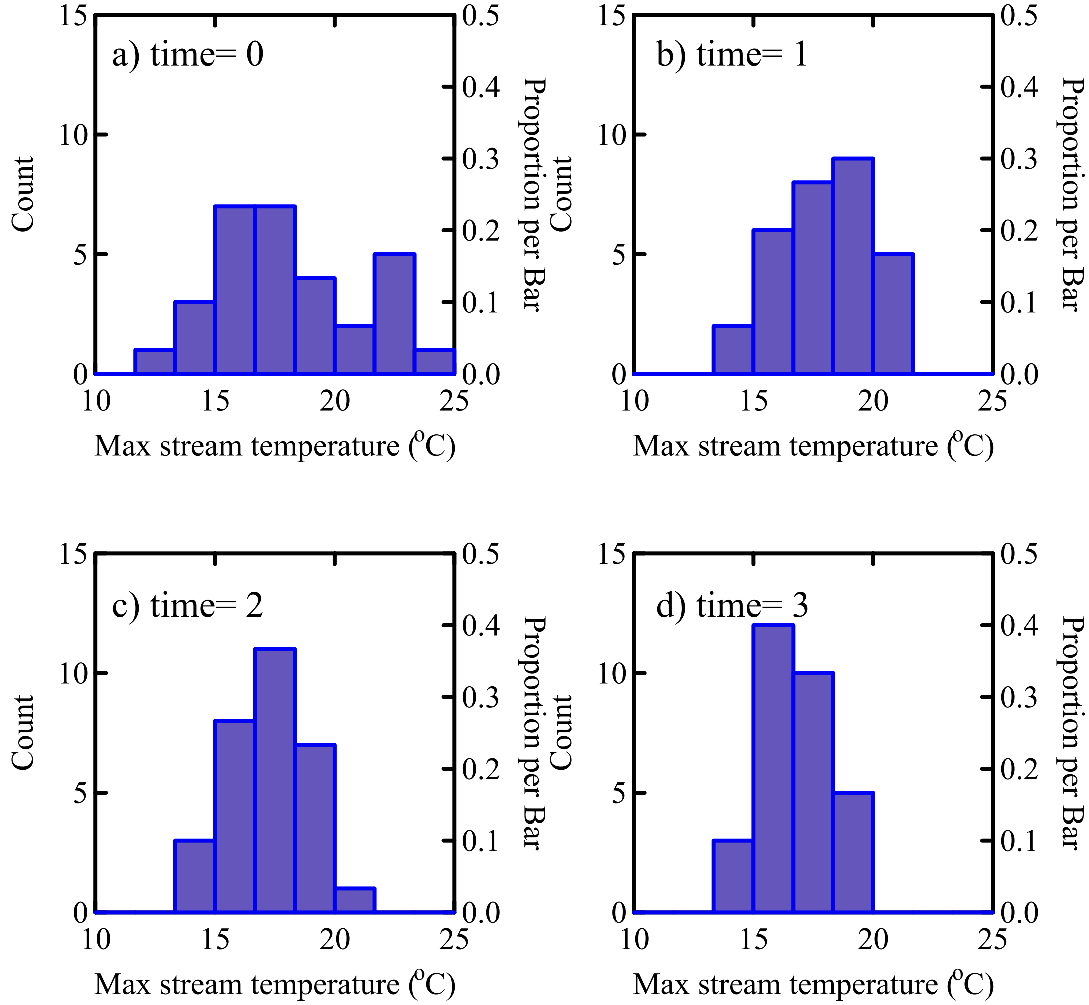

Figure 6. Frequency distribution of maximum stream temperature over time. This scenario shows a shift to the left (decreasing temperature) with increased riparian shade.

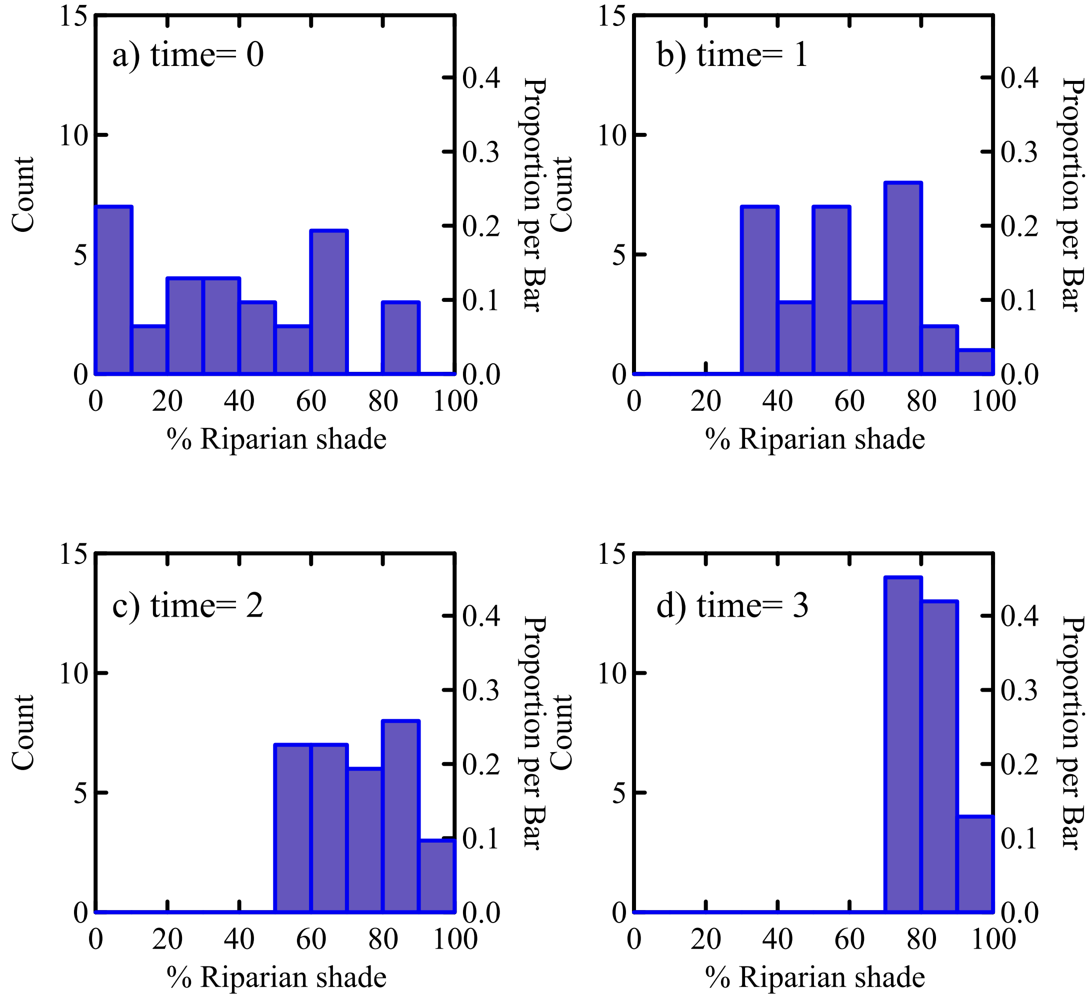

Figure 7. Frequency distribution of riparian shade over time shows a shift toward increased shade as riparian vegetation recovers.

To illustrate, data from 26 western Washington streams (Sullivan et al., 1990) were used to estimate a regression model predicting maximum August stream temperature from maximum August air temperature (Figure 8). If stream temperature decreases between the two sampling seasons as a result of factors other than a difference in air temperature (an increase in riparian shade for example), then the MDT would expect that for a given air temperature, the stream temperature would be lower than predicted by the model. By comparing the distribution of the residuals (observed stream temperature – predicted stream temperature) for current conditions with later sampling periods, a shift toward the left should occur (Figure 9).

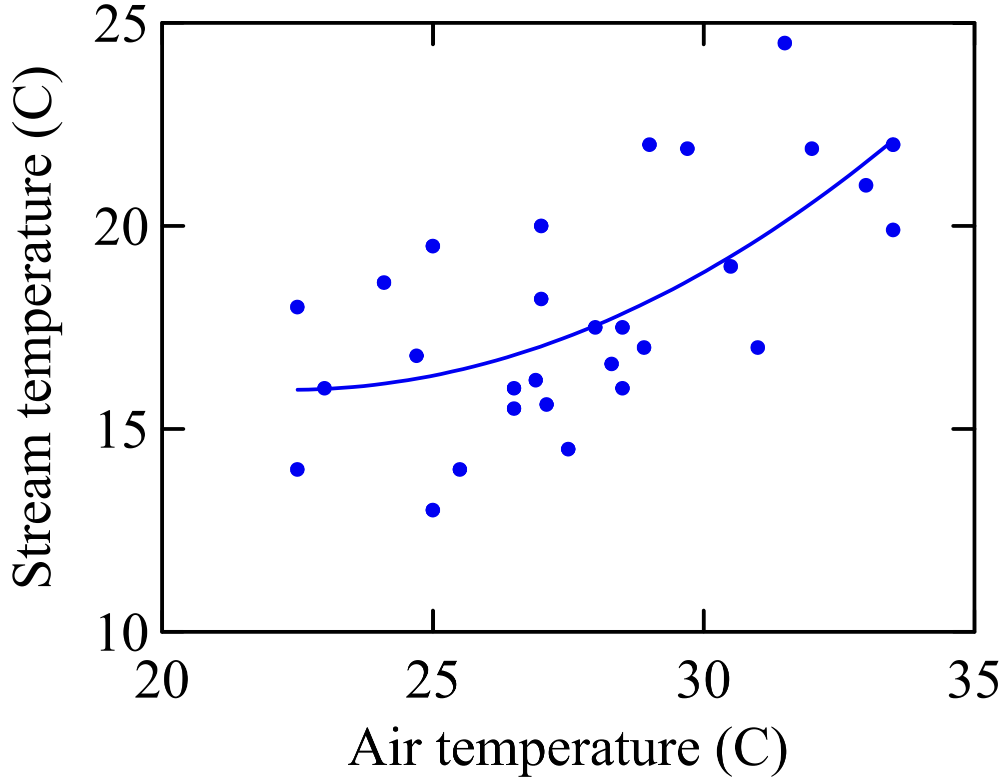

Figure 8. Relationship of maximum August stream temperature vs. maximum August air temperature at 26 sites in western Washington, $P< 0.05$ $r^2= 0.39$ (data from Sullivan et al., 1990).

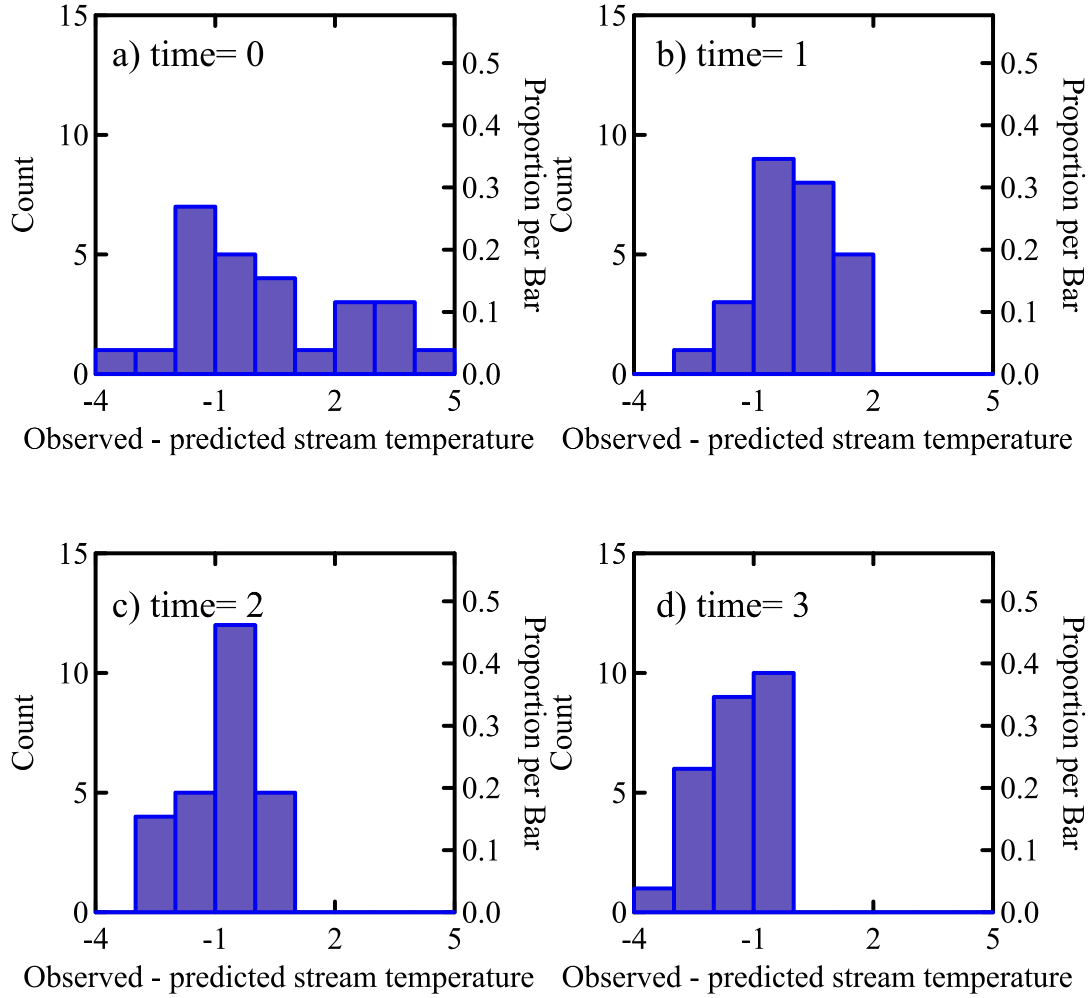

Figure 9. Frequency distribution of residual (observed - predicted) stream temperature. As increased riparian shade results in lower stream temperature, the air temperature-based model will overpredict stream temperature resulting in a leftward shift in the distribution.

This example was made to illustrate how the analysis may be done. The actual model would include those site-specific physical variables that are important factors in determining stream temperature and must include those factors that affect stream temperature (elevation, latitude, channel geometry, basin area) and vary greatly between years (air temperature). Models using the same data and combinations of these predictor variables had r-squared values over 0.70. If improved models are developed, they can be easily applied, retrospectively, to existing data so that the continuity of the analysis is not compromised even if the model is modified.

Evaluation of Results

Performance targets, including state water quality standards and Desired Future Condition (DFC) of riparian stands, were included in the FFR report. However, neither has been validated as to their effectiveness in providing adequate protection of riparian and stream habitat. These performance targets will be used as a measure of effectiveness however they cannot account for the naturally occurring spatial and temporal variability in stream or riparian stand conditions. The extensive riparian monitoring will estimate the frequency distribution of stream temperature and riparian stand condition, and measure several correlated variables over time. Stream temperature in a given reach at a given time is a function many factors, including: geographic location (latitude, elevation, climate), inter-annual variability in weather (air temperature) and changes due to implementation of FFR rules (riparian cover, channel geometry). Stream temperature at a site is impacted to a greater or lesser degree by forest management and so stream reaches will respond to FFR to varying degrees. By measuring some of the covariates that impact stream temperature, the MDT can increase their ability to detect changes in temperature that are due to FFR.

The MDT Recommends Using a Three-Part Approach:

1. *Validate the performance measures.*

Validation monitoring in the intensively monitored watersheds is critical to define explicit targets required to meet the objectives of the FFR. Performance targets need to be appropriately scaled, ecologically relevant, and recognize the natural complexity of these systems.

Stream temperature will be evaluated using the current water quality standards. State water quality standards are reviewed periodically and they will not be addressed here.

2. *Identify reference areas with no or little timber harvest.*

Expand the monitoring program to sites within protected forests to determine the distribution of conditions that exist in the absence of management for timber production or under more restrictive management than FFR. The former includes national parks, national monuments, national recreation areas, wilderness areas, and some smaller parcels of state lands. These data would show the range of conditions and variability over time and space that exists in the absence of harvest. Lands under more restrictive management include federal land that was actively managed for timber production but will now be managed for late seral stage forests under the Northwest Forest Plan. Data from these reference areas will show the trajectory (over time) of riparian and aquatic indicators as recovery occurs. Neither of these reference scenarios should be interpreted as a standard to be met. They would establish a direction for expected changes under FFR and can be used to put the current conditions into a landscape context. Where suitable reference areas do not exist, it may be possible to use existing models to establish a desired range of conditions (Benda et al., 1998; Wimberly et al., 2000). Another approach used in several Puget Sound watersheds (Beamer et al., 2000; Pess et al., 1999; Collins and Montgomery, *in press*) is historical reconstruction of conditions using data from a variety of sources.

To find which areas may be suitable as references, the MDT will determine the ecoregion strata that comprise FFR lands. Protected lands within those ecoregions that comprise a substantial portion of FFR will be evaluated for sampling as reference sites. Each reference area chosen will be explicitly linked to those FFR lands for which it is a reference. Likewise, FFR lands for which no reference area exists will be identified and the potential for modeling reference conditions there will be evaluated.

3. *Estimate the expected rate-of-recovery based on current FFR rules.*

Use existing models to predict the expected rate-of-recovery to provide a realistic, explicit assessment of the probable near-term changes in riparian condition. One means is to link the empirical data collected in the extensive riparian monitoring to a model predicting stream shade as a function of stand growth and physical site characteristics. Welty et al. (*in press*) recently developed the Riparian Aquatic Interaction Simulator. This model builds upon the ORGANON forest growth and yield model (Hann et al., 1995) to predict riparian shade over time. The shade estimates could then be used in a stratum-specific empirical model predicting stream temperature using a suite of site-specific variables including riparian shade. ORGANON requires more intensive riparian stand monitoring than proposed here and will increase costs.

Sample Size

The precision of these stratum-scale trend estimates will depend upon the variability of the residuals of the model within a stratum. In order to estimate the number of sites required, the residuals of the model (Figure 6) were used as an estimate of the unexplained variability. The number of samples needed was estimated using equation 3 below:

$$n = \frac{2s^2}{\Delta T^2}(t_{\alpha(1)} + t_{\beta(1)})^2 \qquad (3)$$

where n= estimated sample size,
s^2= variance of the residuals,
ΔT= minimum detectable difference,
$t_{\alpha(2)}$ and $t_{\beta(1)}$= t values for two-tailed and one-tailed test, respectively (Zar, 1999).

Sample size was calculated for ΔT values from one to four degrees C at 0.5 C increments and for two combinations of confidence and power, α=β=0.05 and α=β=0.10 (Figure 10). Sample size varies depending upon the detectable difference required and the degree of uncertainty tolerated. For example, to detect a change of 1.0 C in maximum stream temperature due to factors other than differences in air temperature would require 86 or 132 monitoring sites for α=β=0.10 and α=β=0.05, respectively. Increasing the detectable change to 2.0 C, decreases the monitoring sites to 22 and 33, respectively. However, these sample sizes are gross estimates. The monitoring sites were not randomly selected but were monitored for specific reasons. Because of this the actual within-ecoregion variability may be underestimated (more than half of the sites were from just two Water Resource Inventory Areas) or overestimated (sites are from several ecoregions which may be different strata). Also, the model used was simple. The model envisioned will be more precise and result in less unexplained variability. The proportion of variance in this data set (Sullivan et al., 1990) explained by elevation, latitude, basin size, air temperature, and shade was 0.70. Similar results have been reported in Oregon (P. Larsen, pers. comm.).

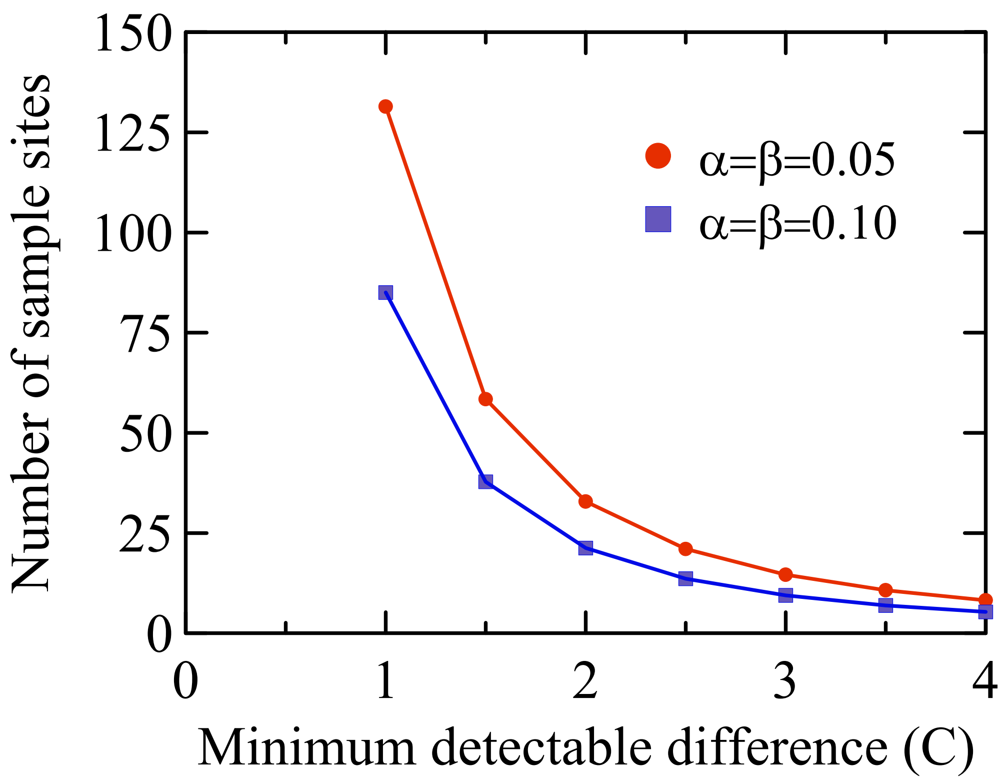

Figure 10. Estimated number of monitoring sites required for a given minimum detectable change at $\alpha=\beta=0.05$ and $\alpha=\beta=0.10$.

Costs

Several steps are needed to complete the monitoring design before total costs can be calculated.

1. In order to determine the number of temperature monitoring sites needed to estimate the current distribution of stream temperatures a random sample of sites will need to be monitored. Two 2-person crews can install monitors and collect site data for approximately 50 sites (Table 7). The difficulty in getting to randomly selected sites and the need for at least two site visits (to install and recover the monitors) make this a time demanding effort. Because of the paucity of data and the uncertainty about the effects of the Type N buffer strategy, the MDT recommends that the initial effort be directed at Type Np streams only.

2. Two statistical design questions need to be answered to complete the monitoring design for riparian stand condition: a) How long a stream reach must be evaluated to obtain a good estimate at a reach-scale?, and b) How many sites must be sampled to obtain a good estimate of the stand condition at a population-scale? Data exist from managed lands in Alaska and Washington (Grotefendt et al., 1996; Martin et al., 1998) which could be used to answer these questions. The MDT will continue to pursue these questions so that costs may be estimated.

Table 7. Estimated cost for extensive stream temperature monitoring.
Includes data storage, analysis, and reporting.

Item	Annual cost
2 2-person crews June-October, plus 3 months for compilation and analysis	$104,000
Travel	$ 32,000
Equipment	$ 5,000
TOTAL	$141,000

Extensive Fish Passage Monitoring

This section describes the extensive monitoring plan for fish passage at locations where forest roads cross fish bearing streams (hereafter referred to as crossings). The monitoring plan focuses on obtaining, maintaining, and analyzing status and trend data for fish passage at these locations. This plan relies on existing tools (WDFW's fish passage manual and hydraulic model) for predicting whether or not crossings are fish passage barriers and the ability of this tool to accurately make this prediction. One limitation of this approach is that it is based on the swimming ability of specific salmonid species and life stages for which data are available. Data for the swimming ability of juvenile salmonids and other non-salmonids is lacking. This tool should be validated at the prescription scale. Prescription level monitoring should also focus on evaluating new water crossing structures (i.e., culverts, fords, and bridges) or other fish passage measures related to road crossings. Prescription level monitoring will be developed and managed by the In-stream Scientific Advisory Group (ISAG).

The policy objectives for road management "will be to maintain or provide passage for fish in all life stages, to provide for the passage of some woody debris, to met water quality standards, to control sediment delivery, to protect streambank stability, and to divert most road run-off to the forest floor" (WFPB 2000). Of these objectives, only fish passage, woody passage, and bank stability pertain to road crossings. The others relate to sediment run-off from roads. This report will focus on fish passage because tools are readily available to assess these criteria. No such tools exist for quickly measuring wood passage and/or bank stability, and evaluations would be subjective in the absence of these tools. Monitoring plans for these criteria can be developed later once tools have been developed. In addition, the turn "some wood" needs to be clearly defined at the policy level prior to developing and implementing a monitoring strategy for this particular measure.

Fish was defined by the FFR as "species of the vertebrate classes of Cephalospidomorphi and Osteichthyes." Improving fish passage is one of several criteria used to prioritize basins or road systems for maintenance and repair. The effectiveness of fish passage prescriptions at restoring and maintaining passage is also listed as an important research question in FFR (WFPB 2000). This plan assumes that culverts will comprise the largest proportion of forest road crossings observed and that they will likely pose the most serious problem for fish passage.

Provisions in FFR allow timber companies 15 years (beginning in December 2000) to complete activities listed in the RMAPs, i.e., all fish passage barriers are to be corrected by year 15. In addition to verifying that all fish passage barriers have been corrected, the change in the proportion of barriers through time is used as an indicator that RMAPs are on trajectory to meet the intent of the FFR. The goal of this monitoring element is to develop a status and trend database for forest road crossings throughout the State, which can be used to determine (1) the current proportion of road crossings that are fish passage barriers, and (2) the rate of decline in the proportion of fish passage barriers over time.

These data will be used to test the following hypotheses.

Ho_1:Less than 5% of the road crossings of fish bearing streams are fish passage barriers.
Ha_1:Greater than 5% of road crossings of fish bearing streams are fish passage barriers.

Ho_2:The proportion of road crossings on fish bearing streams that are fish passage barriers during the current survey is greater than the previous survey.
Ha_2:The proportion of road crossings on fish bearing streams that are fish passage barriers during the current survey is less than the previous survey.

Hypothesis one is obviously the objective of the FFR (no fish passage barriers). A target of five percent was used rather than zero, the actual FFR goal, to provide a measure which can be tested statistically.

Design

Selecting sampling locations for fish passage is complicated because that there is not complete list of road crossings on fish bearing streams on lands influenced by FFR. However, this information may be available in the future, as RMAPs are completed by landowners (required within five years of signing FFR). Sampling is further complicated by the fact that the repair of fish passage barriers will not be randomly dispersed over space. Repairs will likely be clustered along road segments, which may cause clustered sampling designs to produce biased results. Random sampling designs result in clustering by nature (Overton and McDonald 1998) and therefore, would potentially provide biased data.

Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) site selection process will be used to overcome the problems stated above. Sample site selection will follow the methods outlined by Firman and Jacobs (2001). Fish bearing streams within FFR lands will be identified using the currently excepted fish model. GIS will be used to place a grid over the stream overlay. Stream segments within grid cells will be labeled, removed from the overlay, and linked to form one continuous line. A random point will be selected along this line;

with subsequent points selected at equally spaced intervals until the desired sample size is obtained. These points will then be displayed at their actual location along the fish-bearing stream network. The road crossing closest to each point will be sampled for fish passage. Finding the closest road crossing will require examination of historic and recent aerial photos, and road maps to identify potential road crossings. This may be the case only during the first year, since current road maps will not be available for all areas. However, road overlays produced during the development of RMAPs may be available during subsequent years. Selected locations will then need to be verified during field evaluation prior to data collection.

Sampling will occur at 5-year intervals. Thus, background data will be collected in year 1 and subsequent surveys would be completed in year 5, 10, and 15. One exception to this would be that sampling would occur during year 7 if a significant improvement in the proportion of barriers were not observed between year 1 and 5. This sampling scheme should allow enough time for improvements in fish passage to occur. It also provides reasonable time periods to assess fish passage, which allows improvements to be made between successive samples.
Road crossings of fish bearing streams closest to the selected points within FFR lands will be selected and assessed for fish passage. This site selection will occur for each year sampling occurs. Thus, sites sampled during the first year, will have the same probability of being selected during subsequent surveys as sites not selected during the first year.

Our analysis shows that there are 320 WAUs with 3.56 million acres (5,500 square miles) of FFR lands in the State. Crossing densities, based on one WAU within the southern Cascades ecoregion, is estimated to be 1.12 crossings per square mile (B. Bilby, personal communication). Assuming this represents the entire state, there are approximately 6,200 crossings within the state. Our sampling strategy would result in 1.6 to 5.4 percent of crossings sampled for fish passage each survey depending on which hypothesis is being tested.

Data Collection and Analysis

Data for this assessment will be collected at each crossing following methods outlined in WDFW's fish passage assessment manual (WDFW, 2000). However, both a level A and a level B assessment will be done at each site to determine passage status. Data requirements for a level A assessment include presence/absence of substrate in the culvert, culvert width, streambed toe width, outfall drop, and culvert slope. Data requirements for a level B assessment include water surface elevations, culvert elevations, and cross-section data. Data from level B assessments are entered into a spreadsheet developed by WDFW, which completes hydraulic calculations and provides a conclusion regarding the fish passage status of the culvert. This program (in several formats) is available from WDFW or the WDFW website. A full description of the level A and B methods are available from WDFW or can be downloaded from WDFW's web page (www.wa.gov/wdft/hab/engineer/fishbarr.htm).

The Fisher's exact test (Zar, 1999) will be used to test the two null hypotheses. Table 8 provides an example of this data analysis using a hypothetical data set. If this null hypothesis (i.e., barriers constitute less than to 5 percent of all road crossings) is rejected, the data will be analyzed to test the hypothesis that the proportion of crossings that are barriers is being reduced. The Fisher's exact test (Zar, 1999) will be used to compare the proportions of crossings that are barriers during the current survey with that observed during the previous survey. Table 9 provides an example of this analysis for a hypothetical data set.

Table 8. Example of results from the Fisher's Exact Test for hypothetical data sets (n = 340). Each test compares observed frequencies of barrier and non-barriers data from a survey with the expected frequencies, which are based on the goal of having less than 5 percent of all crossings as barrier. The results indicate that the goal (<5% barriers) was met during year 15.

	Observed		Expected		
Year	Barrier	Non-Barrier	Barrier	Non-Barrier	P
Year 1	170	170	17	323	<0.0001
Year 5	120	220	17	323	<0.0001
Year 10	70	270	17	323	<0.0001
Year 15	28	312	17	323	0.0610

Table 9. Example of the Fisher's Exact Test to compare the proportion (number) of crossings that are fish passage barriers during the current survey to the proportion observed during the previous survey. Comparison of year 5 to year 1 indicates that significant improvement did not occur. The remaining comparisons indicate that significant improvements occurred.

Year	Barrier	Non-Barrier	Comparison	P
Year 1	60	40		
Year 5	50	50	yr 5 vs. yr 1	0.1004
Year 7	40	60	yr 7 vs. yr 1	0.0035
Year 10	20	80	yr 10 vs. yr 7	0.0016
Year 15	10	90	yr 15 vs. yr 10	0.0367

Sample Size

Sample size requirements need to be considered for both the above hypotheses. Although, these two hypotheses are tested using the same statistic (Fisher's exact test), the sample sizes for these two tests cannot be calculated using the same method. Because the proportions in the final test (year 15) should be small (0.05), the normal approximation method described below is inappropriate (Zar, 1999). For hypothesis 2, comparing current proportion of barriers to historic proportion of barriers, the proportions will change over time. Changes in the proportions being compared will also influence sample size.

Sample sizes were estimated for hypothesis 2 using the following formula:

$$n = \frac{A[1+(1+(4\delta/A))^{1/2}]^2}{4\delta^2}$$

where

$$A = [Z_{\alpha(1)}(2pq)^{1/2} + Z_{\beta(1)}(p_1q_1 + p_2q_2)^{1/2}]^2$$

$$p = (p_1 + p_2)/2 \qquad q = 1 - p$$

and

p_1 and p_2 are the proportion of barriers observed during the last and current sample periods, respectively; δ is the desired difference (p_1-p_2); and

$Z_{\alpha(1)} = t_{\alpha(1),\infty}$.

Two different scenarios for initial and subsequent proportions of fish barriers for powers of 0.90 and 0.75, respectively were used to calculate sample size. First, the existing proportion of road crossings that are barriers (those observed during year 1) was assumed to be 0.60 and that a detectable change in the first five years was 0.2 (or 1/3 of the barriers are corrected in 1/3 the allotted time). The second scenario assumes that the proportion of crossings that are barriers will be 0.4 at year five and 0.2 at year 10. Results for these sample size calculations are shown in table 10.

The sample size calculation for the hypothesis that less than five percent of road crossings were fish passage barriers was calculated through an iterative process to determine what proportion of barriers would result in significant differences from the expected 5% using the Fisher's Exact Test with varied sample sizes. The goal was to determine the point where increasing sample size provided relatively little benefit for detecting differences from the goal of 5% fish passage barriers. This was completed using alpha levels of 0.05 and 0.10. Results from this analysis are shown in table 11.

Table 10. Sample size estimates for the Fisher's exact test using $\alpha = 0.05$, $\beta = 0.10$ and $\beta = 0.25$, for several different combinations of previous and final proportions.

Alpha	Power (1-β)	Previous Proportion	Final Proportion	Difference	n
0.05	0.90	0.6	0.4	0.2	115
		0.4	0.2	0.2	98
0.05	0.75	0.6	0.4	0.2	77
		0.4	0.2	0.2	66

Table 11. Proportion of barriers required to provide a significant difference from the expected five percent barriers at different sample sizes and alpha levels of 0.05 and 0.10.

	Alpha Level	
Sample Size	0.05	0.10
100	0.130	0.100
160	0.106	0.094
220	0.096	0.086
280	0.089	0.082
340	0.085	0.079
400	0.083	0.075
460	0.080	0.074

Based on these results, 100 samples should be collected until the proportions of crossings that are barriers become small enough to test the hypothesis that barriers constitute less than 5 percent of all crossings. A sample of 340 should be obtained once this hypothesis will be tested. These sample sizes provide good statistical power to detect the desired differences, while balancing the costs of data collection. Once the goal is attained, 100 samples should be collected every five years to determine if the proportion of barriers increases. This test would be completed using a conservative alpha level (0.10) to account for the small sample size. If a significant difference occurred in one of these tests (i.e., barriers make up more than 5% of all crossings) subsequent data collections would include 340 crossings until no more than 5% of crossings were barriers.

Costs

Data acquisition will cost about $34,000/year. Assuming that, on average, three crossings could be sampled each day, assuming that each assessment requires 1 hr. This is within the range of 15 to 90 min. provided by Mike Barber (WDFW, Personal Communication). This allows 1.25 hrs of travel time to reach the first crossing, each subsequent crossing, and return to lodging facilities at the end of the day. Approximately, 100 road crossings should be sampled each time road crossings are surveyed until the final hypothesis is to be tested (probably around year 15). This final hypothesis would be tested using data collected at 340 crossings. Therefore, it will require 33 days (Approx. 7 weeks) to complete all the surveys during a given year up to year 15 when 114 days (23 weeks) will be required to obtain all samples. These samples should easily be collected during a single summer field season. Two people would be required for these assessments and the daily charge for each person will be $500/day. This charge includes overhead, travel, and equipment. An additional $10,000/year would be required for determining sampling locations, data entry, analysis, and reporting. These figures were calculated using a biologist rate of $800/day.

The total cost for this monitoring activity will be $44,000 per year. Note that these figures do not include inflation following the first year. Table 12 provides a breakdown of costs per year assuming an inflation rate of 5% per year. This monitoring work will cost over $100,000 by year 20 using this inflation rate. The overall cost of this monitoring work ranges from $481,000 to $540,000 for the first 20 years. The cost will be the smaller of the two values if a significant trend is observed after year 5, because sampling will not occur during year 7. The larger costs will occur if a significant improvement is not observed after year 5.

Table 12. Yearly cost associated with extensive monitoring of fish passage at road crossings. Costs increases from year-to-year represent an increase due to inflation (5%). Two total cost estimates are provided which reflect whether or not sampling occurs during year 7. Sampling will occur only if a significant improvement (reduced proportion of barriers) is not observed between years 1 and 5.

Year	Cost
1	$44,000
5	$54,000
7[a]	$59,000
10	$68,000
15	$296,000
20	$111,000
Total (with yr 7)	$540,000
Total (minus yr 7)	$481,000

[a] Sampling will occur during this year only if there is not a significant improvement from year 1and 5.

This extensive monitoring plan relies upon readily available tools, which use the existing physical conditions at the site, to determine if a barrier is passable to fish. One shortcoming of this approach is that these tools are available only for adult and older juvenile salmonids. Another concern is that current barrier repair guidelines recommend that the stream simulation approach be used when repairing culverts determined to be blockages. The stream simulation approach is recommended, because it is assumed to be the only way to ensure the FFR goal of providing passage for all life stages of fish will be met. However, these design criteria have not been validated. These tools should be validated at the prescription level. Validation of the fish passage model should be completed by collecting the physical data normally collected to assess fish passage along with actual fish passage data (fish movement through a crossing using mark/recapture methods). This should be completed at sites classified as barriers and non-barriers. These data should be analyzed to determine the accuracy of the physical passage model in determining if a site is a barrier. This information should be used to modify and/or update the fish passage model as required. Thus, it is very important that data collected for each crossing under this extensive monitoring program be retained, so it can be re-analyzed at a later date if necessary. More research should be conducted to determine the swimming abilities of juvenile salmonids and other non-salmonids. Data similar to that described above for validating the fish passage model should be collected to validate the assumptions of culverts replaced using the stream simulation methods.

It is important to note that the current fish passage criteria pertain primarily to adult salmonids. Therefore, extensive research is needed to develop fish passage criteria for other fish present in streams covered by the FFR. Some of this research is currently being completed in a cooperative effort between the Washington State Department of Transportation and WDFW. However, the focus of this research is juvenile salmonids.

Data collected for this monitoring program will supplement that collected by the Washington State Departments of Transportation (WDOT) and Fish and Wildlife (WDFW). WDOT and WDFW currently complete and fund culvert inventories. However, these inventories are primarily completed on state and county highways, and those of small landowners. Data collected during this monitoring program will be entered into the database maintained by WDFW's SHEAR program.

The following tasks need to be completed prior to implementing data collection for this sampling strategy:

1. Identify fish bearing streams within lands influenced by FFR.
2. Complete site selection using EMAP methodology.
3. Locate the closest road crossing to the selected points using historic and current aerial photos and road maps (GIS data).
4. Verify that the selected crossings are actually the closest crossing to the selected point along the stream network.

Additional road crossings may be added to the potential number of crossings once the assessment of orphan roads is complete. FFR states that "an inventory of orphan roads will be required to be completed in the first 5 years after adoption of the rule package. Once the extent of the problems associated with orphan roads in known, the authors of this report (FFR) will evaluate if the hazard-reduction statures (RCW 76.09.300 through 320) are still needed and if funds for cost-sharing are needed to effect repair or abandonment of orphan roads." (WFPB, 2000).

Roads (monitoring plan under development)

Mass Wasting (monitoring plan under development)

Intensive Monitoring

Introduction

Including intensive monitoring in a monitoring design provides the ability to better identify interacting factors influencing aquatic habitat quality and distribution and generates information of sufficient detail to begin to develop some understanding of the biological effects of FFR. Intensive monitoring provides the best avenue to evaluate the interaction of individual prescriptions, enabling the results of prescription effectiveness studies to be interpreted in terms of the contribution of prescriptions to habitat quality and biological condition (Figure 11). Without the detailed information generated by intensive monitoring, the causative agents of many of the patterns of change observed through prescription monitoring and extensive monitoring cannot be identified.

Relationship Among the Three Scales of Monitoring

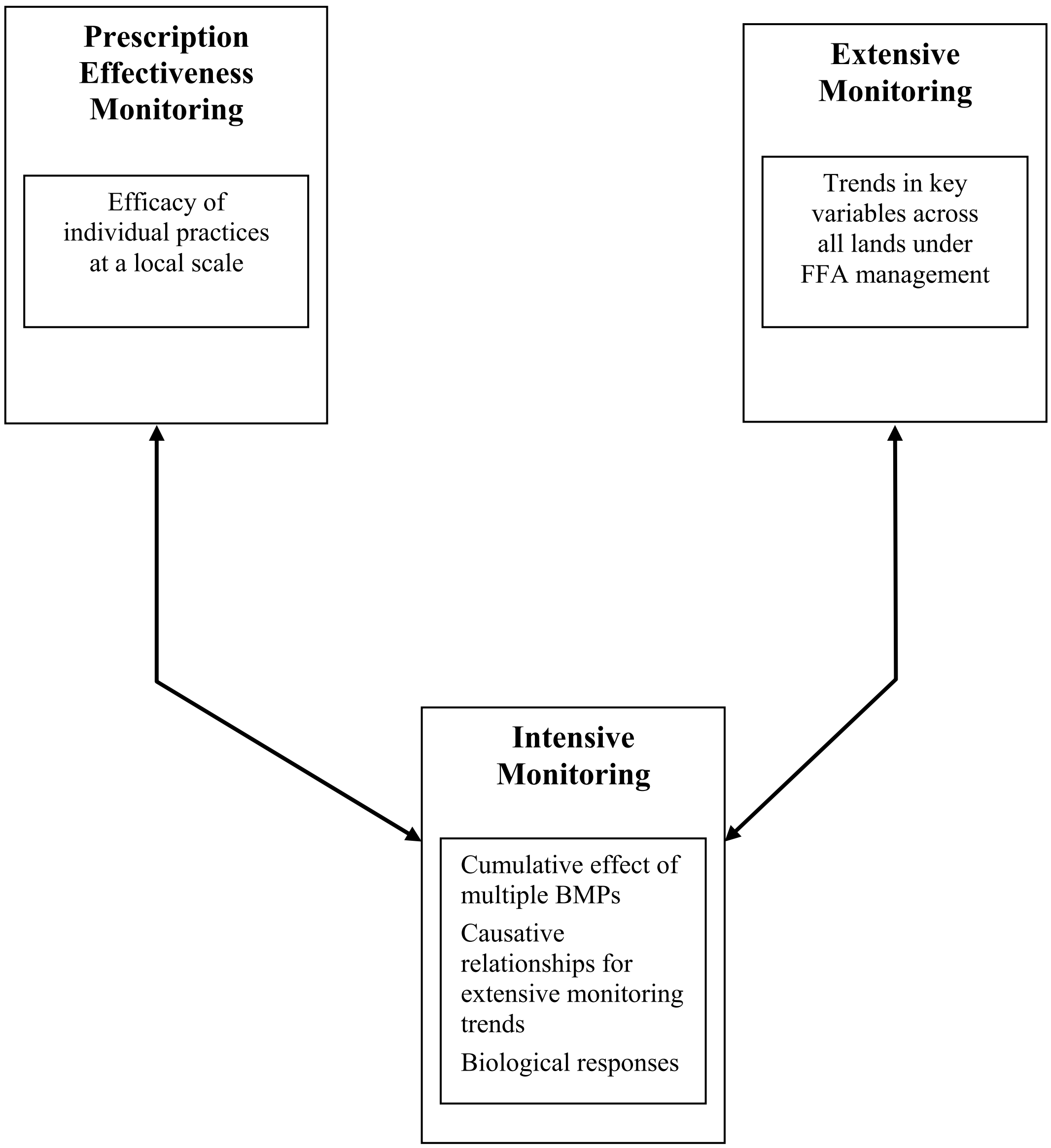

Figure 11. Relationship between monitoring at the three spatial scales. The primary objective of each monitoring type is shown in the boxes. Intensive monitoring provides the link between the fine-scale information about individual BMPs and the large-scale, long-term trends in parameters provided by the extensive monitoring. Including the intensive monitoring piece greatly enhances the value of information collected at the other two scales.

Intensive research and monitoring in a single location has provided results that have been very influential in guiding the evolution of forestry practices. Some of the earliest intensive monitoring efforts in forested landscapes were instituted by the U.S. Forest Service in the 1950s to better understand hydrologic responses to logging. Efforts at these sites expanded over time to encompass chemical and biological responses as well. Changes in forest practices nationwide have been based on studies conducted at experimental watersheds like the H.J. Andrews Experimental Forest in Oregon, the Hubbard Brook Experimental Forest in New Hampshire and the Coweeta Experimental Forest in North Carolina. The success of these efforts spawned a number of intensive, watershed-level research efforts in the Pacific Northwest to evaluate the response of salmon to forest practices. The Alsea Watershed Study, which was initiated in the 1960s and continues today, evaluated the response of coho salmon and cutthroat trout to various logging methods in a series of small watersheds on the Oregon coast (Bisson et al*., in press*). Early results from this study provided some of the impetus for the revision of laws governing forest practices in Oregon and Washington in the early 1970s. In the 1970s an ambitious watershed-level project was initiated at Carnation Creek on Vancouver Island, British Columbia that evaluated the response of coho and chum salmon to the logging of a previously unlogged watershed. The results of this study led to a revision of the forestry code for B.C. and also influenced revisions to forest practice rules in other areas of the Pacific Northwest. The influence of these types of monitoring efforts emphasizes the value of dedicating a portion of monitoring resources to intensive monitoring.

Questions Addressed with Intensive Monitoring

Closely spaced measurements in space and time are often required to develop a thorough understanding of the processes responsible for a system response to a management action. Concentration of monitoring effort in a relatively small area is an efficient method of achieving the level of sampling intensity necessary to determine the full nature of a response. This level of monitoring intensity, and the in-depth understanding that it provides, enables the evaluation of two important aspects of the effectiveness of forest practices that cannot be addressed with other approaches; cumulative effects of multiple practices and biological responses. Evaluation of cumulative effects of multiple management actions on a system requires an understanding of how individual actions influence a site and how those responses propagate through the system. This understanding will enable the evaluation of the effectiveness of management practices applied at multiple locations over time. This sophisticated level of understanding can only be achieved with an intensive, integrated, monitoring effort. Evaluating biological responses is similarly complicated, requiring an understanding of how various management actions interact to affect habitat conditions and how system biology responds to these habitat changes. The complexity of evaluating biological response is illustrated by the diversity of habitat types required by a coho salmon to complete freshwater rearing (Table 13). The response of the fish is dependent on the relative availability of the numerous habitat types it requires and the sensitivity of these habitat types to forest practices, which will vary depending on the practice and habitat type. The issue is further complicated as the importance of each habitat type and the effects of forest practices on these habitats change from year-to-year due to variations in weather, abundance of fish spawning within the watershed and other factors. For example, smolt production can be dictated by spawning habitat availability and quality during years when flood flows occur during incubation and greatly decrease egg survival (Pess et al., *in press*). However, during years of more benign flow conditions during egg incubation, population performance may be more influenced by the availability of food during spring and summer or adequate winter habitat.

Table 13. Changes in the habitat requirements of coho salmon during freshwater rearing. The changing requirements of the fish stress the need to develop monitoring designs that evaluate responses at a spatial scale large enough to encompass the full range of habitat types required by the fish to complete freshwater rearing. Habitat types or attributes required to support one aspect of the life history can be evaluated at a site scale. However, determining how these factors cumulatively affect survival and growth of the fish through their entire period of freshwater rearing requires a large-scale, integrated monitoring effort best accomplished in an intensive setting.

Life History Stage	Habitat
Spawning and egg incubation	Gravel bedded riffles and pool tail outs in proximity of cover suitable for adult spawners (e.g., deep pools, undercut banks, debris jams)
Early fry rearing	Low velocity with cover in close proximity to food source typically associated with shallow, channel margin habitat with cover from wood and overhanging vegetation
Summer rearing	Pool habitat with cover in close proximity to food source typically associated with low gradient channels, pool/riffle morphology, streams in flood plain valley type
Winter rearing	Low velocity refuge with cover typically associated with off-channel habitat on floodplains including low gradient tributaries, secondary channels and ponds

Untangling the various factors that determine performance of the salmon and how these attributes are influenced by forestry can only be accomplished with an intensive monitoring approach. As the biological response is the ultimate measure of the success or failure of the FFR prescription package, developing this level of understanding is critically important for evaluating the effectiveness of the new rules. Concentrated sampling in a series of intensively monitored Watershed Administrative Units (WAU) can provide the type of comprehensive data needed to understand these relationships.

In addition to providing detailed cause-and-effect information on system response to FFR prescriptions, intensive monitoring also can provide information that can help in refining performance standards and desired future conditions. The intensively monitored WAUs will provide detailed data on the relationship between physical and biological attributes and how they respond to FFR prescriptions. This type of information will enable the determination of whether the application of a suite of prescriptions actually has the intended effect on the ultimate resources being managed (fish, amphibians, other aquatic biota, and water quality). Not all performance standards can be assessed within the intensive WAU. For example, some standards must be developed and validated at spatial scales larger than a single WAU, such as those related to mass wasting. However, as the intensively monitored WAUs can provide an opportunity to implement controlled experiments at fairly large spatial scale, they do provide an opportunity to critically evaluate and improve many performance standards.

Some general design considerations for intensive monitoring are addressed below. However, the specific characteristics of an intensive monitoring effort will depend upon the questions being addressed. In order to illustrate how questions would be addressed in intensively monitored WAUs, two examples of specific questions that could be addressed by intensive monitoring are provided.

Spatial Scale and Regional Representation

The spatial scale at which intensive monitoring is conducted is dependent upon the question being addressed (Schneider 2001). The response of a single channel segment to the application of a management prescription can be adequately addressed at a very small scale. However, most of the more interesting and pertinent questions regarding the effectiveness of the new forest practice rules require evaluations at a much larger spatial scale. This is especially true when attempting to evaluate biological response of migratory species such as salmon. An area large enough to encompass the full range of habitats required for the salmon to complete freshwater rearing is the smallest experimental unit at which a comprehensive evaluation of the effect of FFR on these fish can be conducted. Certainly, biological responses of other groups of organisms could be adequately conducted at smaller scales but given the focus of FFR on improving the production of salmonid fishes, these animals should be included in the evaluation process.

For these reasons, the basic sampling unit for intensive monitoring should be an entire WAU. Selecting this relatively large area provides the opportunity to evaluate physical, chemical and biological effects of FFR at hierarchical spatial scales ranging from the reach through sub watersheds of the WAU to the entire WAU.

In order to obtain adequate representation of conditions in forested areas across the state, ideally, an intensively monitored WAU would be located in each ecoregion that contains a significant amount of forest land that will be managed under FFR. The WAUs selected within each ecoregion should contain conditions representative of the key sensitivities occurring in that area. For example, a WAU selected for intensive monitoring in southwestern Washington should contain areas prone to management-induced landslides, as this is a key issue FFR attempted to address and a common problem in this region. Similarly, as bull trout are a key concern in eastern Washington, WAUs selected for intensive monitoring in these ecoregions should contain this species in order to evaluate it's response to the prescription package.

Monitoring Objectives

A conceptual model of the manner in which forest practices may influence watershed behavior can be used as a basis for establishing intensive monitoring objectives. This type of simple model can illustrate how the different monitoring parameters may interact and how they ultimately may affect biological resources of interest. The influence of forest practices on watershed conditions may be viewed as a set of hierarchical, interacting processes and attributes (Figure 12). Some of the watershed attributes, like climate and geology, are largely unaffected by land use but as these factors create the physical template for the system they are key determinants of the behavior of a watershed and how the system responds to forest practices.

Influences of forest practices on vegetation, by harvest and stand management, and on sediment and hydrology through roads, can influence a variety of watershed processes. Changes in these processes can then affect the distribution and quality of aquatic habitat that, in turn, influences biological characteristics of the system like fish populations. Understanding the functional linkages between management actions, watershed processes, habitat condition, and biological response provides a mechanism for linking prescription effectiveness evaluations with habitat quality and productivity of aquatic biota. These models also help identify those factors that could be responsible for trends revealed by extensive monitoring and aid in developing intensive studies to evaluate the potential cause-and-effect relationships.

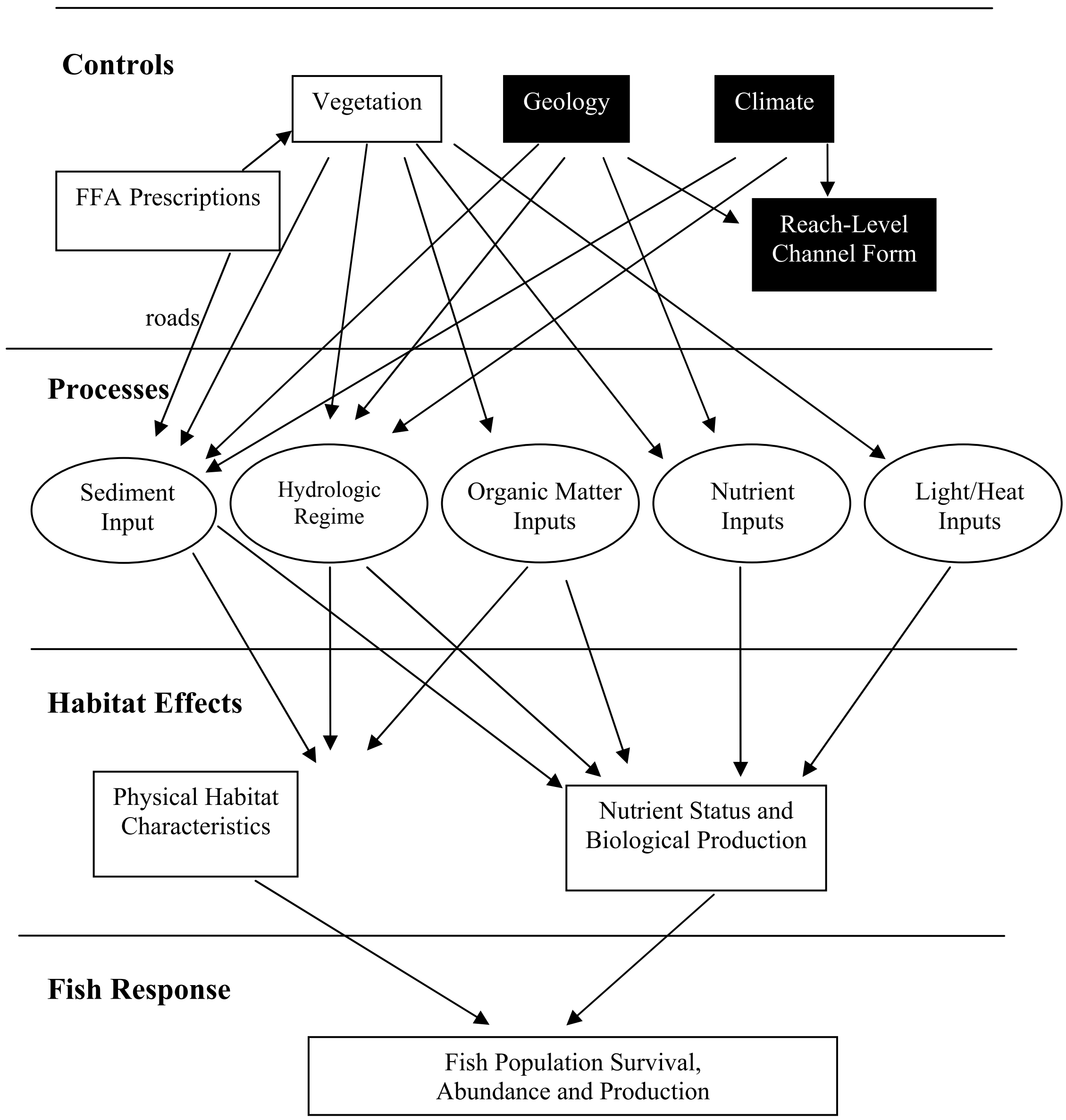

Figure 12. Conceptual representation of the interaction of factors influencing salmon population responses in a watershed. Boxes in black represent system components not influenced by land management. FFR prescriptions are intended to minimize the effect of forest practices on watershed processes. Prescriptions potentially influence multiple processes and these changes can be propagated through the system, affecting habitat attributes and fish populations. Intensive monitoring will provide some understanding of the magnitude of these responses under FFR.

Figure from Beechie et al. (*in press*).

Experimental Design

A before-after/reference treatment experimental design is well suited to address many of questions amenable to intensive monitoring. This type of design enhances the ability to differentiate treatment responses (effects of prescriptions) from responses due to variations in weather or other factors not directly affected by current experimental treatments.

Treated and untreated sites can be paired at a multiple spatial scales within an intensively monitored WAU, the scale dependent on the question being addressed. For monitoring questions that can be addressed at local scales, reference sites within the intensively monitored WAU could be identified. These reference sites would consist of portions of the WAU comparable in initial condition to the location where FFR prescriptions are applied but where little or no management activity would occur during the period of evaluation. Questions that can be addressed at this finer scale include life-history specific biological responses or physical habitat responses to multiple management actions. This approach has the advantage of not requiring a “pristine” site as a reference. The monitored conditions at the treated site should exhibit differential change relative to the reference location, regardless of initial condition. For example, application of a suite of measures to reduce sediment delivery to streams in a subwatershed of a WAU would be expected to reduce turbidity and deposited sediment in the channel relative to a reference subwatershed where these treatments are not applied. The use of relative change in conditions as the response metric offers considerable advantage over approaches that require reference sites in pristine condition, as unmanaged sites will be very difficult to locate in many areas of the state. Some appreciation of the range of conditions in unmanaged WAUs is useful as it can provide a context for determining the suite of conditions ultimately desired in a managed watershed (see section on performance standards). However, this knowledge is not absolutely necessary when making proximate judgments about the efficacy of management actions.

For evaluations of FFR effects at the scale of the entire WAU, a comparison with a nearby WAU that is largely unmanaged (e.g., wilderness or park) would be most appropriate. However, in situations where an unmanaged reference WAU is not available, a WAU undergoing management under a different set of prescriptions (e.g., HCP) or at a significantly lower level of intensity (federal forest land) could be used as a reference. Using this approach, relative changes in the parameters being monitored between the treated and reference WAU would have to be interpreted in light of any management activities at the reference site that could be impacting the measured parameters. However, differential response between the treated and reference WAUs would provide an indication of relative prescription effectiveness. For example, a comparison of salmon freshwater survival and production between a WAU managed under FFR and a WAU managed under the Northwest Forest Plan could provide an indication of the relative effectiveness of the FFR prescription package for fish.

Monitoring Variables

As with any scientific investigation, the variables measured depend upon the hypotheses being tested. Nonetheless, there are certain key measures of system response that are fundamental to assessing FFR prescriptions. For example, the question of the cumulative effects of FFR on sediment might entail the development of several subwatershed level sediment budgets in each monitored WAU involving the measurement of sediment input, transport, and deposition. The advantage of addressing multiple questions in these intensively monitored WAUs is that the interactions among the various response variables can be evaluated. For example, the effect of FFR prescriptions on a subwatershed sediment budget could be related to salmon habitat quality and quantity and abundance, growth and survival of the fish.

Some of the variables measured under intensive monitoring will be the same as those examined in extensive monitoring efforts or for evaluation of prescriptions. Examples might be water temperature or riparian canopy cover. The primary difference is the frequency, spatially and temporally, with which the samples are collected in an intensive monitoring effort. Intensive monitoring also will include a suite of variables typically not measured in effectiveness monitoring at the other two scales, especially those related to the biological characteristics of the sampled WAU. Biological measurements often involve so much effort that obtaining these measures across large areas, as would be required in an extensive monitoring effort, is prohibitively expensive. Prescription evaluations are often done at a single site and biological responses might not be meaningful at this scale.

The variables measured in common in intensive, extensive and prescription monitoring efforts enables integration across the three scales and enhances the ability to interpret the results (Figure 11). Prescription monitoring provides the basic understanding of how a few variables respond to the application of a single forest practice prescription at a given site. Extensive monitoring provides an indication of the temporal trend in resource conditions over large landscapes. Usually these extensively monitored parameters are features that are influenced by multiple forest practices as well as natural characteristics of the watershed. Without a thorough understanding of the processes controlling the variables measured in extensive monitoring, the causative factors for the observed trends cannot be determined. The intensively monitored watersheds enable the response to a specific prescription and the broader patterns of environmental change seen in the extensive monitoring effort to be connected. The intensive monitoring approach relies on a level of sampling intensity not possible at the other two scales. This level of sampling intensity is necessary to distinguish between natural and management-related changes in watershed attributes and enables the factors responsible for an observed change in condition to be identified. Focusing some of the prescription evaluation efforts in the intensively monitored WAUs and including extensively monitored sites in these WAUs will enhance the linkages among these three monitoring scales. Without any one of these monitoring approaches, understanding of the effectiveness of the FFR prescriptions would be incomplete.

Focal Studies in the Intensively Monitored WAUs

It is possible to address a very large number of questions related to FFR prescriptions with the intensive approach. Realistically, only a few key issues can be addressed at one time. A rather lengthy list of possible projects amenable to the intensive approach is provided below. This list is not intended to suggest that all, or even, most of these projects would be undertaken from the outset. Rather they are included to provide an indication of the types of question that are best addressed by concentrated effort at relatively few locations. The intent of the following section is not to provide detailed instruction for intensive monitoring but only to give a general idea of the questions, possible types of measurements and methods of data interpretation that are available at this monitoring scale. The details in the examples provided below may vary depending on site conditions and available resources. However, due to the complexity of these questions, they are most appropriately addressed with an intensive watershed approach.

Cumulative Effects of FFR on Sediment

Forest practices can accelerate the delivery of sediment to streams by increasing the frequency of occurrence of landslides and generating surface erosion, especially from roads. A number of FFR prescriptions are designed to reduce the generation and delivery of sediment to stream channels. The efficacy of individual prescriptions at a single site can provide an indication of the degree of control provided by that method. However, the cumulative effectiveness of all measures to reduce sediment input through and entire watershed cannot be assessed unless a sampling scheme is designed to specifically address this question. This type of evaluation does provide an excellent opportunity to couple prescription evaluation with a basin wide determination of the overall effectiveness of sediment management under FFR.

The appropriate experimental units for this evaluation do not have to be as large as an entire WAU. However, the areas assessed should be of sufficient size that a range of FFR prescriptions that have the potential to influence sediment generation and delivery are applied at multiple locations. Often this criterion can be satisfied within a subwatershed of a WAU; an area of 2,000 to 5,000 acres. Measurements within subwatershed where FFR prescriptions are applied can then be compared with other, comparable subwatersheds within the WAU where prescriptions will not be implemented during the period of evaluation. The subwatersheds chosen for a reference in most cases will have been subjected to forest practices in the past. However, as the response variable is the relative change in the amount of sediment delivered and deposited in streams in the treated and reference subwatersheds, previously managed subwatersheds can be used as a reference for this evaluation, provided that no prescriptions are applied in this subwatershed during the study period.

Parameters measured in this assessment would include those that relate to sediment generation, both natural and management related, and deposition and transport in the channel. Sediment generation, transport, and deposition tend to be spatially segregated in a subwatershed, due to differences in channel gradient and discharge (Montgomery and Buffington 1998) and measurement of each of these processes should be focused on an appropriate channel reach. Thus, generation measurements would be focused at locations where most sediment is produced and deposition measurement would occur downstream of major source areas where gradient decreases. Suspended sediment transport would be measured at the downstream end of the treated and reference subwatershed. Differences in sediment generation rates, bed form, particle size distribution of the bed substrate, and suspended sediment concentration between the treated and untreated subwatersheds would be used to judge the effectiveness of the prescriptions for sediment.

Objectives

Determine whether application of FFR prescriptions designed to minimize sediment production will:

- Have an effect on sediment generation and delivery from mass wasting and surface erosion.
- Produce measurable changes in amount of sediment deposited at response reaches.
- Have an impact on suspended sediment levels.
- Affect biological attributes at response reaches.

These questions may be addressed by comparing the generation, deposition and transport of sediment before and after treatment between multiple pairs of treated and reference subwatersheds. Measurements that might be taken during this evaluation would include:

- Identification and characterization of the major sediment sources, both natural and management-related, prior to prescription application – these sites will be the focus of measurements to evaluate sediment generation rates during the study.
- Response in sediment generation to application of FFR prescriptions.
- Sediment deposition rates at response reaches and effect on channel form.
- Suspended sediment and flow at the downstream end of treated and reference sub watersheds.

Examples of the types of measures that might be included in an evaluation of cumulative sediment generation and delivery and how the monitoring results could be interpreted are provided below.

Mass Wasting

Sediment Generation

- Photo-interpretation of landslide frequency for the period for which photos are available; determine frequency and surface area and volume of sediment delivered to channels.
- Field surveys at the start of the study and periodically thereafter to determine the proportion of landslides visible on photos and to determine the landslide rate in the study subwatersheds after the application of the FFR prescriptions.
- Field evaluation of recent landslides to determine volume of sediment generated.
- Using the sediment volume data in conjunction with the landslide rates determined from the photos and field surveys, generate estimates of volume of sediment generated through time.
- Relate mass wasting frequency and volume of sediment generated to storm frequency and intensity before and after implementation of the FFR prescriptions for mass wasting.

In-Channel Effects

- Periodically map channel geometry, bed surface particle size composition and type, distribution and volume of habitat units (e.g., pools, riffles) at multiple response reaches.

Surface Erosion

Sediment Generation

- Use existing methods (Watershed Analysis protocols) to determine location and relative magnitude of fine sediment delivery from road segments in the monitored subwatersheds.
- Verification of estimates of sediment delivery from roads with current methodology.

- Measure sediment delivery from selected road segments to stream channels: Automatic samplers at ditch entry to stream or frequent grab samples during periods of ditch flow.
- Flumes on ditches at sediment measurement sites to determine discharge to stream.

In-Channel Effects
- Delineate channel reach types and identify response reaches (i.e. those most likely to respond to changes in sediment input volumes).
- Measure turbidity at the downstream end of the study subwatersheds and at selected stream reaches representing a cross-section of road densities and traffic intensity.
- Determine sediment transport and storage in representative channel types.
- Measure substrate particle size distribution at response reaches.
- Measure substrate particle size distribution and volume of interstitial space in type N streams.
- Measure pool volume at response reaches.

Biological Response
- Compare egg-fry survival of salmon and trout among subwatersheds.
- Evaluate feeding rate and growth rate of salmon fry relative to turbidity.
- Compare abundance of non-salmonid fishes.
- Determine relative density of larval amphibians during summer in type N channels in the study subwatersheds above and below road sediment sources.

Sediment Budget - Integration and Interpretation of Monitoring Results

- Use relationships developed above to determine sediment input, transport, and deposition for each monitored subwatershed.
- Track changes in sediment dynamics over time as FFR sediment prescriptions are implemented.
- Compare sediment behavior with reference subwatersheds – if prescriptions are effective, generation of sediment related to management actions should decline and channel conditions and water quality should improve more rapidly in the treated subwatershed relative to the reference subwatershed.

Articulation with Other Monitoring Elements
- *Prescription Effectiveness Monitoring*
  Effectiveness evaluations of sediment abatement techniques at individual sites.
- *Extensive Monitoring*
  Evaluation of road sediment abatement with application of various road management and abandonment plans.

Cumulative Effects on Wood

A considerable amount of research attention has been devoted to better understanding the effects of various types of riparian treatments on wood delivery to channels. This information has recently been incorporated into models that enable wood abundance and resultant channel characteristics to be predicted (Beechie et al., 2000; Welty et al., 2001). However, most of this research has been at the scale of individual stream reaches and accounts for wood input only from the adjacent riparian stand. There is far less understanding of the temporal and spatial variability in wood abundance among stream reaches and how the full range of FFR prescriptions influences this distribution.

Some recent research has emphasized the important role mass failures can play in the delivery of wood to streams and in the transport of wood from lower order to higher order channels (May 2000). Thus, the efficacy of the FFR prescriptions for wood needs to consider prescriptions for both riparian areas and mass wasting. An effective way to examine the dynamics of wood in entire drainage basins is with a wood budget (Benda et al., 1998). Using a budgetary approach at the level of an entire WAU provides the opportunity to examine FFR prescription effects on wood input from various sources, redistribution once the wood has been delivered to the drainage network, longevity in the system and the response by aquatic biota.

Objectives

Determine the effect of the FFR prescriptions relating to wood on:
- Wood input to channels, including piece size, quantities, and species.
- Distribution of wood in the drainage network.
- Channel morphology and physical habitat for fish and amphibians.
- Biological characteristics.

Types of Measures

Wood Input
- Conduct a WAU-wide characterization of riparian stand condition using protocols similar to those applied at the extensively monitored riparian sites.
- Establish a series of riparian plots at sites representative of the types of riparian vegetation and management strategies being implemented in the WAU.
- Resample the plots to determine tree growth rate and mortality, changes in species composition and wood delivery to the channel.
- Characterize the density, species and sizes of trees retained on unstable sites.
- Survey mass failures deposits (pre and post FFR prescription implementation) to determine amount of wood delivered to channel and how this parameter changes after implementation of the FFR prescriptions.

Wood Transport and Depletion
- Tag wood or use low-elevation aerial photography (pole-mounted camera) in a multiple reaches, representative of the reach types and sizes in the WAU and periodically resample after major floods to determine wood movement.

Wood Budget
- Use data for wood input developed at the riparian plots to determine wood input rate by channel and stand type.

- Use input rates and the basin wide characterization of riparian conditions to estimate wood delivery from riparian stands.
- Estimate wood input, timing, and distribution from mass failures pre and post FFR implementation.
- Use tagged wood pieces to determine wood redistribution due to fluvial transport and depletion rate in the channel network.
- From these analyses, create a wood input-output budget for the WAU.
- At 5-year intervals, reconstruct the wood budget using data collected in the intervening period to determine if wood abundance, size, and distribution is changing in the desired direction.

Habitat Effects

- Measure change wood-associated habitat features in response reaches through time.
- Measure change in wood-associated organic matter storage through time.

Biological Response

- Measure summer and winter fry densities of salmon and trout relative to wood distribution in the channel network.
- Determine seasonal growth rate from emergence through smolting in relation to wood abundance.
- Evaluate species-specific response of stream amphibians to changes in wood abundance.

Interpretation of Results

- If successful, wood abundance and piece size in the WAU will increase through time.
- The rate of change will be dependent on the growth and mortality of riparian trees and rate of mass wasting and the amount of wood entrained by landslides and debris torrents.
- An expected rate of change can be determined at the initiation of the experiment using data on current riparian condition, existing models of stand growth and mortality and knowledge of the past history of landsliding in the basin.
- If successful, wood abundance changes in the channel will cause corresponding changes in pool frequency and size and sediment and organic matter storage.
- As habitat improves, fish utilization at sites which collect large amounts of wood will increase and the frequency of sites with high wood abundance will increase.

Articulation with Other Monitoring Elements

- *Prescription Effectiveness Monitoring*
  Desired future condition validation
- *Extensive Monitoring*
  Riparian condition evaluation (aerial photo interpretation)

Cumulative Effects of Harvest on Type N streams on Type F Water Temperature

Riparian management for type N streams consists of a combination of a continuous leave area for 500’ above the junction with type F water and a discontinuous patch buffer upstream from that point to the initiation of perennial flow. The effect of such a buffering strategy on water temperature in the Type N stream will be evaluated in prescription effectiveness monitoring. However, evaluating the effect of harvest along multiple type N streams on water temperature in a downstream type F will require sampling at larger spatial scales over long time frames. This type of effort is well suited for the intensively monitored WAUs, where corresponding data on weather, discharge and other pertinent factors can be used to enhance interpretation of the water temperature data.

The objective of this effort can be addressed through comparison of water temperature patterns in subwatersheds that will be actively harvested during the evaluation period and those that will undergo little or no harvest. Thermographs will be deployed along all type N and F channels, following the spacing protocol described for extensive monitoring of temperature.

Objectives

Determine whether implementation of the FFR riparian prescriptions on type N streams influences water temperature in downstream, type F streams.

Types of Measures

Water Temperature
- Use recording thermographs to collect water temperature data from May through October in all tributaries of selected subwatersheds.
- Locate a weather station at an open site within each subwatershed to collect air temperature and total solar radiation.
- Measure discharge at the top and bottom of each type N channel and above and below each tributary junction in the type F channel every 2 weeks during the summer to determine groundwater input.

Biological Response
- Measure fish community composition, density, growth, survival, and production during the summer in the type F channels relative to water temperature.
- Evaluate the interaction between fish density, growth rate, temperature regime, and food availability.
- Evaluate amphibian summer growth rate and distribution within the type N channels relative to temperature in the study subwatersheds.

Interpretation of Results
- Evaluate the rate of warming in type N streams as water moves from the patch buffer section to the continuous buffer to the type F junction.
- Determine rate of warming of type F water as type N tributaries enter.
- Compare warming rate of type F reaches between treated and reference subwatersheds.

Articulation with Other Monitoring Elements

- *Prescription Monitoring*
  Water temperature response to different buffering strategies

- *Extensive Monitoring*
  Water temperature trend monitoring

Cumulative Effects on Organic Matter and Nutrient Delivery

Much of the energy that supports the trophic web of stream systems is provided by terrestrial organic matter input from the surrounding forest. Very little is known about the extent to which organic matter input is influenced by management of riparian stands. Generally it is assumed that a riparian zone wide enough to provide wood will be wide enough to provide finer types of terrestrial organic matter. However, this assumption has not been validated. In addition, FFR will attempt to change the distribution of riparian stand conditions, increasing the frequency of conifer-dominated areas to improve the delivery of wood. The effect this will have on the quantity and nutritional quality of finer organic matter has not been determined but could be significant for biological production. Streams too small to support fish will receive less riparian protection that fish-bearing streams under FFR. The extent to which these buffering strategies will influence litter input to headwater channels and the delivery of organic matter to fish bearing reaches downstream is also not known.

The biological response to changes in the amount and form of organic matter delivered to stream channels is highly complex. Reductions in canopy cover and increased light reaching the channel often cause increases in in-stream plant production, usually in the form of algae. The increased amount of algal biomass generated usually does not equal the decrease in input terrestrial organic matter (Bilby and Bisson, 1992). However, algae is much more nutritious than most forms of terrestrial litter and capable of supporting higher levels of biological production by invertebrates and fish than a comparable amount of terrestrial litter (Bisson and Sedell, 1984; Murphy and Hall, 1982; Hawkins et al., 1983; Bilby and Bisson, 1992). Likewise, litter from deciduous trees, shrubs and herbaceous plants are generally of higher nutritional value to aquatic biota that coniferous litter. As these types of plants are typically most abundant along streams following a canopy-removing disturbance, a change in litter type during riparian recovery also may offset the decrease in total litter input. However, the longevity of litter with higher nutrient content is less than it is for the more resistant needles and cones from conifers, possibly influencing availability through the year. The nature of these relationships is unknown for the FFR prescriptions.

Even less is known about the effect of riparian management approaches on the amount and quality of organic matter delivered from headwater streams to downstream reaches. As a significant amount of the organic matter delivered to higher order channels is fluvially transported from upstream reaches, the nature of these effects can have basin-wide implications for biological production. As noted above, there tends to be an inverse relationship between total quantity of terrestrial organic matter delivered and the nutritional quality of that litter. The effect of FFR prescriptions on litter input and trophic productivity of streams will depend on the distribution of riparian stand conditions and the rate at which the amount and nutritional quality of litter delivered to head water channels changes after harvest.

Objectives

Determine if organic matter input, transport and utilization is altered by the application of the FFR prescriptions in a manner detrimental to aquatic productivity.

Types of Measures

Organic Matter and Nutrient Input

- Determine the amount and type of litter delivered by various stand types and riparian treatments on fish bearing and non-fish bearing streams.
- Determine the nutrient content of the major types of organic matter delivered to the channel.
- Measure dissolved nutrient delivery from groundwater, precipitation, throughfall, and stemflow at sites representative of riparian conditions and prescriptions.
- Measure primary production in the channel at sites where nutrient data is being collected.

Organic Matter and Nutrient Utilization and Transport

- Assess dissolved and particulate organic matter transport at Type F-N junctions downstream before and after harvest along the type N stream. Measure total amount in transport and characterize seston quality by measuring nutrient content and chlorophyll *a* and quantify invertebrate drift.

Biological Response

- Determine invertebrate community composition and production in type N stream reaches before and after harvest.
- Determine invertebrate community composition and production in type F reaches downstream from type N reaches with varying riparian conditions.
- Measure the seasonal production rate ($g/m^2/d$) of the fish community at these sites (requires determination of survival and growth rates of each fish species).
- Measure summer and fall larval densities of amphibians in type N channels and determine larval growth rate.

Interpretation of Results

- The FFR management strategy for type N streams should provide for sufficient litter input the type N streams tributary to a type F to maintain the quantity and quality of material delivery to the type F stream.
- Secondary production (fish and invertebrates) in the type F channel will not decline as the watershed is harvested.

Articulation with other Monitoring Elements

- *Prescription Effectiveness Monitoring*
  Evaluation of different buffering methods on type N and F streams for litter input.
- *Extensive Monitoring*
  Extensive monitoring of riparian conditions.

Response of Biological Attributes to FFR Management

As fishes, especially salmonids, and stream-breeding amphibians were a key focus of the FFR rules package, emphasis should be placed on understanding how these animals respond to application of the full suite of FFR prescriptions. There are various other biological attributes that also could be monitored in conjunction with the fish and amphibian measures to evaluate the effectiveness of FFR. These biological assessments are best done in an intensive monitoring setting due to the sampling effort required to obtain appropriate biological data and the frequency with which these measurements must be taken.

The scale at which biological evaluations are conducted is dependent upon the FFR prescriptions and biological responses being evaluated. Some biological responses to prescription application can be evaluated at the reach level and related to application of a single management action. For example, the biological effects of a prescription to reduce the delivery of road surface sediment at a road crossing could be evaluated by comparing characteristics of the invertebrate community upstream and downstream of the road before and after implementation of the prescription. However, the more interesting biological questions must be assessed at spatial scales too large to be related to the application of a single FFR prescription. These responses must be evaluated at the subwatershed or whole WAU level. For fishes, questions appropriate for evaluation at the subwatershed level often are related to a single stage of their freshwater life history. For example, effects of road building and riparian management in a subwatershed could be related to performance of coho salmon, steelhead, and resident trout by evaluating survival during incubation and survival, growth and production during juvenile rearing. Effects of practices on the trophic dynamics of a system also can be conducted at the level of a subwatershed as the effects of FFR prescriptions on nutrient and organic matter delivery, primary production and invertebrate abundance and community composition can be evaluated at this scale. Some of these biological parameters are included in the descriptions of cumulative effects evaluations provided above.

However, some of the most significant biological responses, especially for anadromous fishes, require evaluation at the scale of the entire WAU. These fishes use a wide array of habitat types during freshwater rearing. Therefore, the scale at which the evaluation is conducted must be large enough to provide the full compliment of required habitat types. For coho salmon, steelhead and sea run cutthroat trout, a WAU is generally large enough to fulfill this requirement. The ultimate effectiveness of the application of the entire suite of FFR prescriptions for salmon and trout is reflected by the performance of the fish through their entire period of freshwater residency. This performance may be evaluated by measuring survival, growth rate, or production during freshwater rearing. For instance, survival can be estimated from the number of eggs delivered to the system and the number of smolts from that cohort that ultimately leaves the WAU. These WAU-level assessments can be coupled with evaluations of effects of FFR prescriptions on specific habitat types and life stages conducted at finer spatial scales, both within the intensively monitored WAU or elsewhere, to provide the information needed to evaluate the effectiveness of the rule package for fishes.

Other species (e.g., ocean-type chinook and chum salmon) typically use an area larger than a single WAU during freshwater rearing. These fishes often use main river channels to rear, sites where effects of forest practices would be combined with impacts from other land uses making it difficult or impossible to assess their response to forest practices. However, those aspects of the life history of these species that occur within an intensively monitored WAU can be related to the FFR prescriptions using this approach.

Regardless of the prescriptions being evaluated or the scale at which the evaluation is being conducted, the biological attributes selected for monitoring should be those most sensitive to the primary input variables being affected by the FFR prescriptions applied in the study area. As noted above, certain life history stages of fishes are more sensitive to sediment that others. Biological evaluation of the FFR prescriptions related to sediment should focus on the most sensitive biological attributes (Table 14).

Table 14. Salmon and trout life history stages most sensitive to various input parameters potentially affected by FFR prescriptions. Biological response variables selected for monitoring should be those most sensitive to the input variable being evaluated.

Input Parameter	Salmonid Life History Stages most Sensitive to Input Parameter
Sediment	Incubation survival, summer survival, growth and production, distribution
Wood	Summer and winter survival, growth and production, distribution
Temperature	Summer rearing survival, growth rate relative to food availability and production
Hydrology (high flow)	Incubation survival, early spring survival

Additional biological measures also are often useful in evaluating the effectiveness of management prescriptions. Certainly, evaluation of the response of amphibians to the application of various management actions is an appropriate response variable, especially as stream-breeding amphibians were a focus of the FFR agreement. Amphibians are relatively immobile, compared to salmon. Thus, evaluation of their response can be done at a finer scale than for fish. However, these animals may respond to changes in sediment, wood input or temperature and the physical effects of a single management action cannot be associated directly to a response by the amphibians. Invertebrates also can be used as an indication of biological response but also will respond to system changes potentially influenced by a variety of FFR prescriptions. For amphibians and invertebrates, as for fishes, careful experimental design and coupling of the biological assessments with comprehensive evaluation of the physical response of the system to the prescriptions being applied can enable the determination of the approximate contribution of each FFR measure to the observed biological response.

Objectives

Determine the changes in the biological attributes of aquatic ecosystems resulting from the application of the FFR prescriptions including:

- Aquatic and riparian habitat quality and distribution.
- Primary production.
- Invertebrate composition and production.
- Fish (egg-fry survival, summer growth and survival, smolts/female).
- Amphibians (species composition, abundance and distribution).

Types of Measures

Habitat Attributes

- Channel reach types, fish use associated with reach types, and the distribution of reach types in the watershed.
- Pool frequency, type and size summer and winter by reach types.
- Wood abundance and distribution in the channel by reach types.
- Riparian condition.
- Bed substrate characteristics by reach types.

Biological Attributes

- Spring and summer chlorophyll *a* accrual rate and periphyton biomass.
- Invertebrate composition, density and biomass seasonally.
- Egg-fry survival at spawning reaches.
- Fry abundance and weight in late spring, late summer and mid winter.
- Smolt output.
- Spawner abundance and sex ratio.
- Abundance of non-salmonid fishes.
- Amphibian diversity and relative abundance.

Interpretation of Results

- Comparison of the distribution of fish with habitat distribution and quality.
- Comparison of biological and habitat attributes in subwatersheds where FFR prescriptions are being applied with reference subwatersheds (unmanaged subwatersheds or managed subwatersheds where no management occurs during the period of evaluation).
- Evaluate changes in the distribution of spawning adult salmon and juvenile salmon during summer and winter to determine if application of FFR prescriptions is associated with alterations in the spatial distribution of the fish.
- Determine if application of FFR prescriptions across the WAU alters the number of smolts produced per spawning female and compare this survival rate with rates for other monitored WAUs that are unmanaged or managed under other prescription packages (e.g., Northwest Forest Plan, HCP).

Articulation with other Monitoring Elements

- *Prescription Effectiveness Monitoring*
  Evaluations of sediment response to implementation of road management and abandonment plans.
  Evaluation of buffering approach on wood input, organic matter input and water temperature.
- *Extensive Monitoring*
  Extensive monitoring of riparian condition and water temperature.
  Extensive monitoring of road condition and sediment production and delivery.

Several sampling approaches are possible for measuring the parameters listed above. Capturing fish seasonally (spring, late summer, winter) by electrofishing, seining or trapping at multiple locations across the WAU would enable an estimate of fish abundance, species, growth rate, and age class composition and would provide a good indication of condition of the populations. Alternatively, a complete survey of fish abundance in all channels using an extensive, visual count sampling approach like Hankin-Reeves (Hankin and Reaves, 1988) could be used, although this method does not provide information on fish species and size that is as accurate as other methods. A combination of the two approaches, a complete survey coupled with subsamples at selected sites where the fish are captured and measured, would provide the most complete information. Counts of adult salmon returning to the WAU to spawn can be conducted with counting fences at the downstream end of the WAU. This method is very accurate but labor intensive and provides no information about spawner distribution. Counts or mark-recapture estimates of spawning fish or carcasses conducted periodically during the time of spawning at index reaches is not as accurate in terms of determining total number of fish but does provide data on distribution. Smolts leaving the WAU must be sampled by using some type of trap. Typical trap types include fences or weirs that capture all smolts exiting the WAU (although fences may become inoperable at high flows), or scoop or screw traps that capture a portion of the fish. Partial sampling traps are easier to maintain and can be used in channels too large for fences. However, these types of sampling devices require frequent calibration to determine the proportion of smolts being captured. A variety of techniques could be identified for the other suggested parameters. The method selected will depend on how critical the measurement is, the characteristics of the site, and the resources to be dedicated to obtaining the measurement.

Spring, summer, and winter counts of juvenile salmonids in the WAU would provide information on the relative abundance of fish in subwatersheds affected by application of FFR prescriptions and subwatersheds not affected. Relative abundance is a better metric to compare fish abundance or density among sites because it minimizes problems with interannual variability in these parameters due to climatic conditions or factors operating outside the basin. One method of normalizing fish abundance data is to express the value for each sampled site as a proportion of the fish captured at all the sites during that sample interval. Responses to the application of prescriptions would be evaluated based on changes over time in the proportion of fish using sites affected by FFR prescriptions relative to untreated sites. Collection of comprehensive abundance data seasonally coupled with data on number of spawning adult fish and number of emigrating smolts enables the determination of survival rates. These data have rarely been collected, but they enable the determination of the effect of freshwater habitat on population performance of salmon (i.e., population growth rate over time) (Kareiva et al., 2000). As a result, these measures are of considerable value in evaluating the efficacy of the FFR prescriptions with regards to fish.

Initial Steps for Implementing Intensive Monitoring Project

Application of intensive monitoring at a pilot project scale on a few WAUs is a reasonable first step to integrating this approach into a monitoring program. The questions to be addressed initially in these WAUs should be closely aligned with ongoing efforts for prescription monitoring and intensive monitoring. Regardless of the physical attributes to be assessed, biological parameters also must be included to begin to develop the data set necessary to ultimately assess the ultimate effectiveness of the FFR prescription package.

Potential WAUs for the Intensive Monitoring Pilot

Establishing a pilot project will require the identification of those WAUs suitable for intensive monitoring. These candidate WAUs should have a high proportion of area managed under FFR rules and viable populations of the biota of interest. Initially the MDT selected candidate WAUs for each of the four largest Level III ecoregions in western Washington (eastside coverage of FFR lands not yet available. See Appendix C. GIS data compilation) based on the proportion of the WAU under FFR rules (Table 15; Figure 13) and then listed the number of anadromous fish, and amphibian species present and the presence of 'currently occupied' bull trout habitat. The minimum percent FFR for inclusion ranged from 60 to 80 percent because the numbers of WAUs with high proportion of land under FFR varied considerably among ecoregions. The anadromous fish distribution data were taken directly from the StreamNet database (Table 16) and the amphibian species distribution (core habitat only) data were from Gap data (WDFW, Table17). This is not intended to be an exclusive list of WAUs but to illustrate the geographic distribution of potential watersheds for intensive monitoring and to outline the procedure for selecting specific WAUs for study.

In order to winnow the list down further investigation into these areas will be needed:

Anadromous fish populations

- Identify the fish populations that are primarily of hatchery origin. Hatchery-origin runs may be included in some studies (effects of hatchery produced fish on wild runs) but could confound a study on the effects of FFR on wild runs.
- Identify the viable runs of each species in each WAU and only consider these. Very weak runs are vulnerable to large relative fluctuations in numbers due to stochastic events or other effects unrelated to land management.
- Determine if there are specific runs or species that must be included in an intensively monitored study for regulatory reasons. ESA compliance may require population-level monitoring in some ESUs.

Bull trout

- Presence of a bull trout population within the WAU.

Amphibians

- Prioritize the amphibian species in Table 12. Because their ranges do not overlap entirely, the relative importance of watershed-scale research on each species should be weighted. Depending upon the species, the questions may be better addressed at other scales.

Spatial distribution of FFR lands

- In addition to the proportion of the WAU under FFR, the distribution of FFR lands within the WAU should also be considered. The effects of non-FFR lands on the biota will vary depending on where they are in the watershed and whether they form a contiguous area or many smaller parcels.

Landowner cooperation

- This research will require close cooperation and communication with the landowner to coordinate the research studies with the pertinent management activities and to compile a harvest history of the basin and planned management activities for the next five or more years. Because this is a test of the effects of FFR, there must be a substantial amount of management planned in the near future.

Table 15. Candidate WAUs were identified in each of the four largest ecoregions of western Washington. The minimum proportion of the WAU under FFR considered varied among ecoregions because FFR lands were not evenly distributed among ecoregions. Some WAUs overlapped ecoregions and were assigned to the ecoregion that comprise > 50% of the area.

WAU Name	WAU #	% FFR	# Anadromous fish	#Amphibians	Bull Trout	Area (ac)
Coast Ecoregion-minimum 80% FFR						
Sekiu Coastal	190301	85	4	3	No	29300
Dickey, W	200419	83	5	1	No	28000
Stevens Creek	220520	80	6	3	No	18800
Chehalis, SF	230113	96	5	4	No	31200
Stillman Creek	230114	87	5	4	No	29700
Chehalis Headwaters	230115	100	5	4	No	45000
Naselle Headwaters	240107	84	5	4	No	48900
Wilson Creek	240304	91	1	4	No	30400
Vesta-Little	240401	94	4	4	No	56300
Fall River	240403	91	4	4	No	26500
Smith Creek	240416	91	5	4	No	43000
North River, Lower	240417	100	5	3	No	44100
Elochoman, N	250203	84	4	4	No	23600
Mitchell Creek	250301	99	4	4	No	25400
Puget Sound Ecoregion-minimum 70% FFR						
Tokul	070412	88	5	1	No	21000
Cedar Creek	260428	86	4	1	No	14400
Silver Creek	260512	71	3	2	No	25600
Cascades Ecoregion-minimum 75% FFR						
White, Middle	100204	87	5	2	No	28500
Wilkeson	100417	93	6	2	No	18100
Newaukum, Upper	230307	85	6	3	No	33000
Skookumchuck	230406	80	5	3	No	40000
Green River	260515	83	6	3	No	46400
Coweeman, Upper	260709	92	4	3	No	47100
Kalama, Middle	270114	90	4	3	No	51500
Goat Mtn	270118	81	4	3	No	42200
North Cascades Ecoregion-minimum 60% FFR						
Howard Creek	010308	64	7	1	Yes	39500
Skookum Creek	010309	61	9	1	Yes	23200
Hutchinson Creek	010310	67	9	1	Yes	14000
Day Creek	030105	79	10	1	Yes	22200
Grandy	040534	65	10	1	Yes	18900
Haystack	070218	67	6	1	Yes	20900

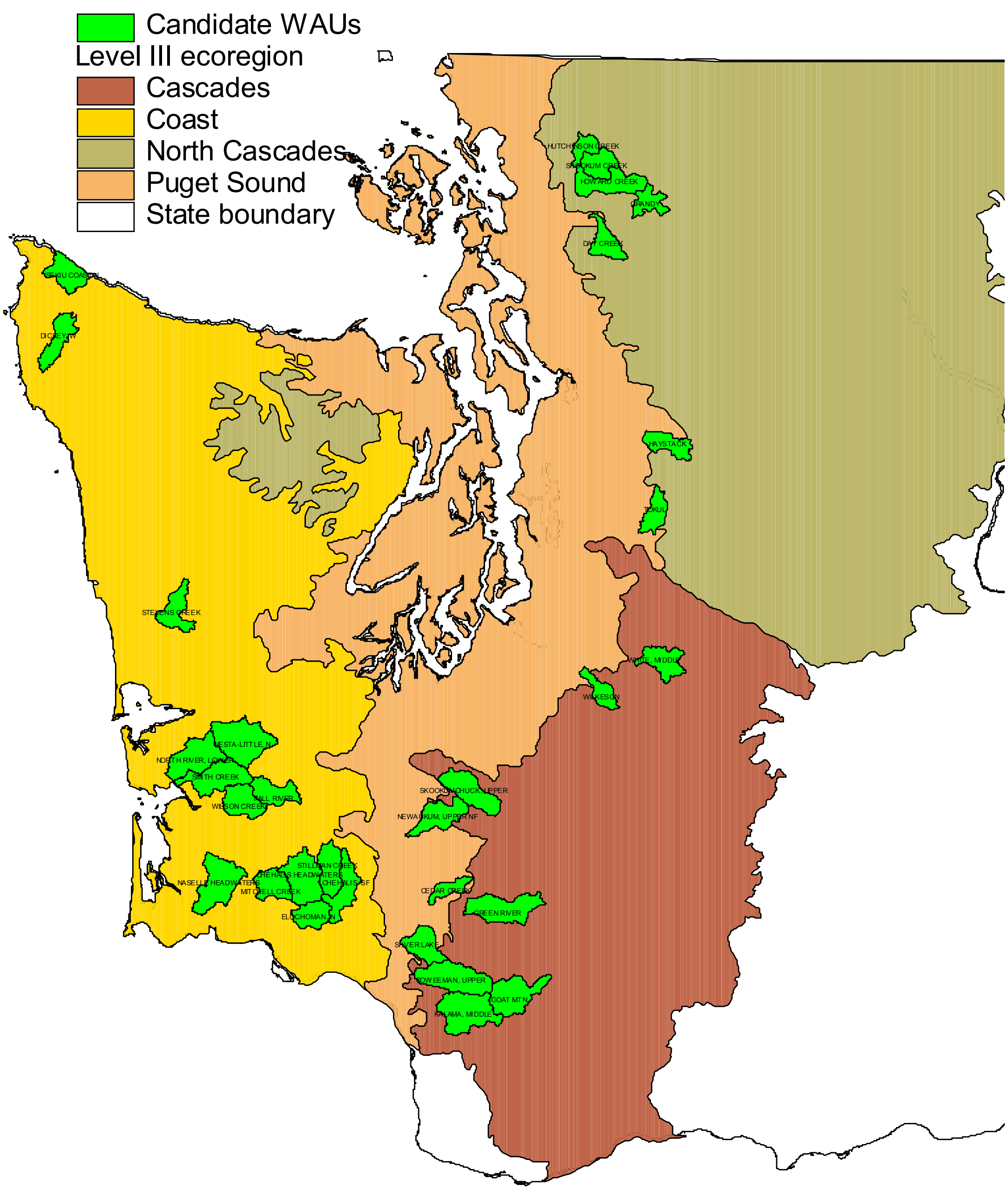

Figure 13. Candidate WAUs for intensive monitoring are highlighted.

Table 16. StreamNet database anadromous fish classifications used to compile anadromous fish presence cover.

Anadromous fish classifications
Fall Chinook
Spring Chinook
Summer Chinook
Chum Salmon
Coho Salmon
Pink Salmon
Sockeye Salmon
Searun Cutthroat
Summer Steelhead
Winter Steelhead

Table 17. Amphibian species used in selecting candidate WAUs.
Only the core habitat was used to tally the number of species present in a WAU.

Amphibian species
Cascade torrent salamander
Columbia torrent salamander
Dunns salamander
Olympic torrent salamander
Van Dykes salamander
Tailed frog

Costs

Assuming that detailed experimental design and data analysis and interpretation will be conducted by collaborators in the FFR adaptive management process, personnel to install and maintain sampling equipment and compile and mange the data sets generated represents the primary expense associated with intensive monitoring. The intensive monitoring efforts implemented in each ecoregion will require a full time person to conduct the routine sampling, maintain the data, and oversee seasonal crews used to collect the types of data requiring additional manpower (e.g., smolt sampling, spawning salmon counts). The level of additional assistance the ecoregion coordinator would require depends upon the degree to which the intensive monitoring efforts could coordinate with ongoing programs that are already measuring some of these parameters. For example, WDFW conducts counts of spawning salmon and measures smolt output in numerous locations. Considerable cost savings could be realized if sites where data is currently being collected occur in WAUs where intensive monitoring for FFR would be appropriate.

Each set of intensively monitored WAUs will require a full-time technician to maintain the weather and flow instruments, collect routine samples and oversee the operation the smolt trap and enumeration of spawning salmon and participate in the collection of other data. The specific studies being undertaken in a WAU, the level of assistance provided by FFR collaborators and the degree of coordination with other research and monitoring programs will determine the amount of seasonal assistance required. The estimate of 1.5 person-years of part-time help assumes assistance will be required for smolt trapping and spawner counts but the coordinator will handle most of the other sampling responsibilities. Personnel costs are estimates that include benefits and overhead costs.

ONGOING ANNUAL COSTS

Personnel (estimates for one year)
Technician and Project Coordinator (full time) 1 person year (@$90,000/yr)
Part-Time Assistance 1.5 person year (@$50,000/yr)
Personnel Costs $165,000

Supplies $25,000
Annual costs for expendable supplies and instrument maintenance

Travel
Field vehicle, gas and associated costs $10,000
Travel to meetings $3000

ONE-TIME COSTS

Instrumentation
Weather, discharge instrumentation, water samplers $80,000

Smolt Trap $80,000

Other Sampling Equipment *$25,000*
(e.g., fish shocker, nets, sample bottles, tools)

Cost for Each Ecoregion (one pair of WAUs)

Year	Total Cost
1	$388,000
Ensuing Years	$203,000

Overall Costs

These cost estimates are based on a several assumptions.

- Costs include only the direct costs of monitoring, not the cost of data storage and database management. As individual portions of the monitoring plan are implemented, the use of existing databases within participating agencies will be evaluated.
- Prescription monitoring is conducted through CMER and these costs are not included here.
- Long-term cost of Extensive Riparian monitoring will depend upon how variable these characteristics are across the landscape and the feasibility of using low-level aerial photography to estimate riparian stand condition. These are being evaluated and the results will be incorporated into later cost estimates.
- Extensive monitoring plans for both Mass Wasting and Roads are in progress and cost estimates are not yet available. The Roads monitoring plan is near completion and existing landscape scale landslide data are being analyzed to guide the development of a mass wasting monitoring plan. These results will be added to this report when available.
- Intensive monitoring costs include the setup and maintenance costs for a single intensively monitored WAU. The individual studies conducted within the WAU would be funded from a variety of private and public research funds. Cost could be substantially less if coordination with existing smolt or habitat monitoring is possible.

Table 18. Estimated first-year costs of monitoring.

	1st year	Following years
Extensive Riparian monitoring	$141,000	Depends upon results of first year.
Fish Passage Barriers	$44,000	Same but sample at 3-5 year intervals
Intensive (cost per pair of WAUs)	$388,000	$203,000
TOTAL	$573,000	$203,000+

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