TFW Effectiveness Monitoring And Evaluation Program

Guidelines for Monitoring and Evaluating Effectiveness Forest Practices and Forest Management Systems

Riparian LWD Recruitment And Shade

Review Draft

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1. INTRODUCTION

In order to provide information for adaptive management within TFW, the TFW Effectiveness Monitoring and Evaluation Program Plan (Schuett-Hames et al. 1998) identifies three main monitoring objectives:

1. To evaluate the effectiveness of specific forest practices and restoration measures in achieving aquatic resource protection and restoration objectives on a site scale, and determine factors that influence effectiveness.
2. To evaluate the effectiveness of forest management systems in achieving aquatic resource protection goals on a watershed scale, and determine factors that influence effectiveness.
3. To document trends in aquatic resources and watershed conditions.

This document supports the first two goals. Section 2 provides guidelines for designing monitoring projects to evaluate the effectiveness of riparian forest practices and restoration measures in regulating thermal energy input and providing large woody debris (LWD) recruitment and associated functions to stream channels at a site scale. Section 3 provides guidelines for designing monitoring projects to evaluate the effectiveness of forest management systems in meeting management objectives for LWD recruitment and shade on a watershed scale.

These guidelines are used by TFW cooperators and the CMER Monitoring Advisory Group to design effectiveness monitoring projects that meet the needs of the TFW Effectiveness Monitoring and Evaluation Program. Monitoring projects designed with these guidelines address the same monitoring questions with standard data collection and analysis procedures, so results from many projects can be compiled by the TFW Monitoring Advisory Group into a common information bank. To participate, TFW cooperators should prepare a monitoring plan that documents the study design and implementation strategy for the monitoring project, and submit it to the CMER Monitoring Advisory Group for review. Additional guidance for preparing monitoring plans is contained in a separate document: “Guidelines for Preparing TFW Effectiveness Monitoring Plans.”

2. EVALUATING THE EFFECTIVENESS OF RIPARIAN FOREST PRACTICES AND RESTORATION MEASURES ON A SITE-SCALE

Riparian forest practices are designed to provide LWD recruitment and regulate thermal energy input by leaving trees adjacent to stream channels. Riparian restoration measures are typically designed to increase LWD recruitment and shade by manipulating riparian stand composition to increase conifer density and the size of individual trees. This section provides guidelines for designing monitoring projects to evaluate the effectiveness of riparian forest practices and restoration measures in producing riparian stands that regulate thermal energy input and provide LWD recruitment on a site scale. Sources of LWD recruitment from outside the riparian stand, such as mass wasting, are not addressed in these guidelines.

The guidelines can be used to design projects that monitor both thermal energy and LWD recruitment functions simultaneously, or that address a single aspect of riparian effectiveness. Steps in the study design process include identifying the project goals objectives, determining the monitoring questions the project will address, developing testable hypotheses, documenting the procedure for evaluating effectiveness, creating a sampling design, documenting monitoring and data analysis methods, and submitting the monitoring plan for review. These steps are described below.

2.1 TFW GOALS, OBJECTIVES AND ASSUMPTIONS

This section presents information on goals, objectives, monitoring questions and evaluation criteria for monitoring site-scale effectiveness of riparian practices and restoration measures. The goals and objectives are based on the more general goals outlined in the TFW Effectiveness Monitoring and Evaluation Program Plan (Schuett-Hames et al. 1998). Monitoring projects should address the program goal and at least one of the program objectives in order to address monitoring questions of concern to TFW and contribute information needed by TFW cooperators and the TFW Effectiveness Monitoring and Evaluation Program to evaluate and improve riparian practices.

2.1.1 TFW Goal

To support adaptive management by evaluating the effectiveness of individual riparian forest practices and restoration measures in regulating thermal energy input and providing LWD recruitment and associated functions to stream channels on a site scale.

2.1.2 TFW Objectives

1. To evaluate the effectiveness of individual riparian forest practices and restoration measures in producing riparian stands at the site that provide adequate levels of LWD recruitment and associated functions over time.
2. To evaluate the effectiveness of riparian forest practices and restoration measures in producing riparian stands that provide adequate levels of shade to prevent increases in stream temperature and to meet the state water quality standard for stream temperature.
3. To evaluate the influence of practice type, site conditions, and other factors on the effectiveness of riparian forest practices and restoration measures, in order to identify

improvements in situations where they are ineffective.

3. To improve interpretation of monitoring results by collecting regional data on tree growth, tree mortality, and LWD recruitment processes in riparian stands, and on the persistence, routing, and function of LWD in stream channels.

2.1.3 Assumptions

Some assumptions on which these study design guidelines are based include:

- Models of stand growth/mortality and LWD recruitment are suitable for developing reasonable monitoring hypothesis.
- It is valid to compare treated sites with unmanaged reference stands of similar age and composition, with similar site and stream channel characteristics.
- Targets for in-channel LWD abundance and stream temperature used to evaluate effectiveness are biologically meaningful and provide adequate protection for aquatic resources.
- Riparian stands comprise the dominant source of LWD recruitment to adjacent stream channels.
- Stream temperature measured at point in the stream channel responds gain or loss of heat within a 600 m long “thermal reach” located immediately upstream of the measurement point.

2.2 TFW MONITORING QUESTIONS AND EVALUATION PROCEDURE

Table 1 lists seven specific monitoring questions that TFW site-scale riparian effectiveness monitoring projects can be designed to answer. For each question, the type of data needed and criteria for evaluating effectiveness are summarized. Question A involves implementation monitoring to determine if riparian forest practices/restoration measures were properly implemented and achieved stand composition requirements over the short term (1-10 years). Questions B and D address the effectiveness of practices in achieving desired effects on riparian inputs and functions (LWD recruitment and shade/thermal energy, respectively). Questions C and E involve validation monitoring to determine aquatic resource response to changes in input of LWD and thermal energy, respectively, associated with the practices. Question F addresses causal relationships between practice effectiveness and site conditions needed for adaptive management to improve practices, and question G involves validation monitoring/research to better understand riparian processes and the factors that affect them.

Table 1. TFW effectiveness monitoring questions related to the effectiveness riparian forest practices and restoration measures.

Monitoring Question	Monitoring Type	Data Needed	Evaluation Procedure
A. How do stand composition/ condition change following application of the practice?	Implementation Monitoring (Stand Composition).	Number, species, height, diameter, distance from stream, and vigor of trees.	Compare stand characteristics with the management system targets. Determine if the stand stabilizes and meets management targets after harvest/restoration and over time.
B. How do LWD recruitment potential and recruitment rate change over time following the riparian practice or restoration measure?	Effectiveness Monitoring (Riparian LWD Recruitment).	Live trees: number, species, height, diameter, distance from stream, and condition. Dead trees: Number, species, length, diameter, fall angle, mortality/ recruitment agent.	There are no accepted targets for recruitment potential or recruitment rates for various stand types. Riparian growth/mortality models will be used to estimate changes in recruitment potential and recruitment rates over time. Actual recruitment potential and recruitment rates will be monitored over time. Recruitment potential, rates and processes in treated stands will be compared with unmanaged stands of similar age and site characteristics to document effects of practices and restoration measures.
C. How do the abundance, characteristics and function of in-channel LWD pieces change over time following the riparian practice or restoration measure?	Validation Monitoring (In-channel LWD response).	Number, volume, channel location and function of in-channel LWD pieces, number of pools, sediment storage.	Watershed Analysis (WFPB, 1995a) targets for in-channel LWD key pieces and percent pools will be used initially but may be modified as site-specific information becomes available from unmanaged stands. Currently no target for sediment storage exists. Data will be interpreted in the context of riparian stand conditions, recruitment rates and off-site impacts (e.g. floods, mass wasting and LWD transport processes).
D. How does shade from the stand change following the practice?	Effectiveness Monitoring (Riparian Shade).	Canopy closure, channel width, elevation	Canopy closure will be evaluated based on whether the shade requirements specified by the management system and the Forest Practices Board manual (WFPB, 1995b) are met.
E. How does the maximum stream temperature change in response to changes in shade following application of the practice?	Validation Monitoring (Stream Temperature Response).	Maximum stream temperature, air temperature, channel width, depth, gradient, elevation.	Maximum stream temperature will be evaluated on whether there is an increase in stream temperature associated with the practice/restoration measure and whether state water quality standards (or more stringent temperature requirements specified by the management system) are met.
F. What factors influence riparian practice effectiveness? How can it be improved?	Effectiveness Monitoring (LWD recruitment and Shade).	Stand age, composition, site productivity, gradient, width confinement, , practice type	Information will be used to identify factors influencing effectiveness and to develop recommendations to improve practices.
G. What factors influence riparian stand growth, mortality, and LWD recruit-ment, routing, and function in streams?	Validation Monitoring (Riparian stand growth and LWD routing).	Same as A, B and C.	No evaluation criteria planned. Information will be used to identify factors influencing changes in stand composition, LWD recruitment rates and processes, and in-channel LWD function and used to develop better evaluation criteria and to validate, improve the predictive capability riparian growth/mortality and recruitment models to reflect site conditions.

The following sections discuss the monitoring approach, data requirements, sampling frequency and evaluation procedures for each of the monitoring questions listed in Table 1.

Question A. How do riparian stand composition and condition change following the riparian practice or restoration measure?

Monitoring Approach: To answer question A, changes in riparian stand conditions in response to riparian practices or restoration measures are monitored from the time of harvest or restoration until the stand stabilizes from the effects of the treatment. The goal is to determine whether the riparian stand is altered by disturbances that occur as a result of harvest (such as windthrow and sun scald) or restoration (such as animal damage or understory competition).

Data Requirements: Data on changes in the riparian stand condition are needed, including the number of live trees, species, height, diameter, distance from stream, condition, and the number of dead trees, and the cause of mortality.

Sampling Frequency: Data collection should occur before harvest (if possible), immediately after harvest, and at one to five year intervals (and/or after major disturbance events) for at least ten years after harvest.

Evaluation Procedure: Immediately after harvest, the riparian stand should meet the stand condition requirements of the management system (typically expressed in terms of tree counts, stand density, or basal area). If it does not, then it is not in compliance due to failure to implement the practice correctly. During the first decade, the riparian stand will be subjected to various stresses related to the harvest or restoration practice. If mortality due to harvest-related stresses causes the stand condition to fall below the management system requirements during this period the practice will be considered ineffective, unless the mortality agents are determined to not be related to the treatment (e.g. volcanic eruptions). At the end of the first decade, the riparian stand is expected to have stabilized from post-harvest disturbance. At this time, the treatment will be considered effective in meeting short-term management system objectives if the riparian stand still meets the management system requirements.

Question B. How do recruitment potential and LWD recruitment rates from the riparian stand change over time following the riparian practice or restoration measure?

Monitoring Approach: Answering question B requires long-term monitoring to determine changes in LWD recruitment potential of the stand (number of trees tall enough to reach the channel and large enough to function) and LWD recruitment rate.

Data Requirements: Data needed to determine changes in recruitment potential include the number of live and dead trees, the species composition, height, diameter, distance from stream, condition, and cause of mortality. Data needed to document changes in recruitment rates include the number, species, length, and diameter of fallen trees, fall angle, and mortality/recruitment processes.

Sampling Frequency: Data collection should occur before harvest (if possible), immediately after harvest, and at one to five year intervals (or after major disturbance events) for at least ten years after harvest and at five year intervals thereafter.

Evaluation Procedure: No accepted criteria exist for evaluating recruitment potential or rates. Many factors make evaluation of the adequacy of LWD recruitment potential and recruitment rates difficult, including differences in site potential, the long time frame over which LWD recruitment occurs, and the episodic nature of some LWD recruitment processes. Consequently, a multi-faceted approach is recommended. First, pre- and post-practice stand data will be run through riparian growth/mortality models to predict LWD recruitment potential (number of trees of functional size tall enough to potentially reach the channel) and recruitment rates (LWD pieces of functional size recruited into the bankfull channel) over time. Pre-and post-harvest predictions will be compared to develop a hypothesis concerning the effect of each practice or restoration measure on recruitment potential and LWD recruitment rates. Then, as recruitment rates and processes are monitored over time, data on actual recruitment potential and rates will be compared with data on recruitment rates and recruitment processes of unmanaged stands with similar site characteristics. The comparison will be used to evaluate the nature and magnitude of changes in LWD recruitment potential, and LWD recruitment rates and processes associated with the harvest or restoration activity. Frequency distributions of tree mortality (by cause), and recruitment processes for treated and unmanaged reference stands will be compared to help interpret differences in recruitment potential and recruitment rates that could be attributed to the harvest activity.

Question C. How does the abundance and characteristics of in-channel LWD pieces and the functions they provide change over time following the riparian practice or restoration measure?

Monitoring Approach: An important objective of riparian practices or restoration measures is to produce stand conditions that provide an adequate amount of functional LWD in the channel over time to perform functions such as pool formation, cover, and sediment routing that produce habitat used by salmonids and other aquatic organisms. However, interpretation of in-channel LWD levels and function is difficult because of confounding factors, including: initial LWD loading at the time the practice occurs; the long time frame required for trees to mature and be recruited to the channel; the episodic nature of many recruitment processes; and the effect of factors unrelated to the practice such as flood events, debris flows, sediment transport and LWD routing. Nonetheless, collection of information on in-channel LWD loading and function is recommended.

Data Requirements: Number, length, diameter, channel location and function of LWD pieces, pool surface area, frequency, and residual depth.

Sampling Frequency: Data collection should occur before harvest (if possible), immediately after harvest, and at five year intervals (and/or after major disturbance events) thereafter.

Evaluation Procedure: As in the evaluation procedure for question B (above), pre- and post-practice stand data will be run through a model to develop a hypothesis about LWD loading and channel response (pool habitat) over time. Pre-and post-harvest predictions will be compared to develop a hypothesis concerning the effect of each practice or restoration measure on LWD abundance, volume, and function. This information will be compared with Watershed Analysis targets for LWD loading and associated functions such as pool formation (Table 2) and with values for unmanaged reference sites with similar site characteristics. However, these data must be interpreted in the context of riparian stand conditions, recruitment rates, and off-site impacts on channel conditions. Effectiveness can also be evaluated by comparing rates of success for several different practice types that are implemented on sites with similar characteristics and initial conditions.

Table 2. In-channel LWD targets for evaluating long-term effectiveness of riparian forest practices and restoration measures (source: Washington Forest Practices Board 1995a).

Habitat Parameter	Channel Type	Target for Practice Effectiveness
LWD pieces/channel width	< 20 m wide	> 2
Key LWD pieces/channel width (western Washington only)	< 10 m wide	> 0.3
	10-20 m wide	> 0.5
Percent pool	< 2%; < 15 m wide	> 55%
	2-5%; < 15 m wide	> 40%
	> 5%; < 15 m wide	> 30%
Pool frequency	< 2%; < 15 m wide	< 2 channel widths per pool
	2-5%; < 15 m wide	< 2 channel widths per pool
	> 5%; < 15 m wide	< 2 channel widths per pool

In order to evaluate long-term effectiveness, it will be necessary to specify a time horizon in which LWD levels estimated by the model are expected to meet the targets. This will be controlled by initial riparian stand conditions, stream size, and initial volume of LWD in the channel. The minimum size for a piece of wood to function as LWD increases with increasing stream size (Bilby and Ward 1989; Kennard et al. 1997), so for large streams that have relatively young riparian stands, it may be many years before the trees grow big enough to begin providing functional LWD to the channel. Conversely, smaller streams may receive functional LWD even with relatively young riparian stands, so the time horizon for evaluating effectiveness should be much shorter. Additionally, it may take many years for sufficient quantities of LWD to accumulate to meet the targets, so channels with a low initial volume of LWD will require more time to pass before effectiveness can be evaluated. With consideration of these factors, approximate time horizons between 0 and 200 years should be specified for the variety of site conditions evaluated in the monitoring project. These numbers can serve as guidelines for evaluating effectiveness, but will need to be refined as more information from modeling efforts and trend monitoring becomes available.

Question D. How does the shade provided by the riparian stand change over time following the riparian practice or restoration measure?

Monitoring Approach: To answer this question, changes in canopy closure over time for the stream channel adjacent to the treated riparian stand will be examined and compared with management system shade targets (Forest Practices Board manual temperature requirement (WFPB, 1995b) unless superseded by Watershed Analysis, Habitat Conservation Plan or Landowner Landscape Plan prescriptions.

Data Requirements: Mean canopy closure, channel width and elevation adjacent to the treatment site.

Sampling Frequency: Data should be collected prior to the treatment, immediately after treatment, and at one to three year intervals until the stand stabilizes or reaches management system requirements. Monitor after major disturbance of the riparian stand thereafter.

Evaluation Procedure: Mean canopy closure for the adjacent reach will be compared with the shade requirements of the management system or the forest practices board manual for the temperature region and elevation of the stream to determine effectiveness. For treatments where pre-practice shade exceeds management system requirements, post-practice shade levels should continue to meet management system shade requirement over time. For treatments where pre-practice shade levels do not meet management system shade requirements, no loss of shade should occur and the potential for the stand to develop additional shade to meet management system requirements should not be impaired. For riparian restoration practices that do not meet management system requirements, a trend or trajectory towards the management system target should occur. For riparian restoration projects where pre-treatment shade levels meet the management system target, shade should continue to meet requirements or if temporary loss of shade is allowed by the management system (as in some Watershed Analysis prescriptions), canopy should re-establish adequate shade to meet the management system requirements within the time-frame specified by the prescription.

Question E. How does the maximum stream temperature regime change over time in response to the riparian practice or restoration measure?

Monitoring Approach: To answer this question, changes in canopy closure over time for the stream channel adjacent to the treated riparian stand will be examined and compared with the management system targets.

Data Requirements: Summer stream temperatures at the upstream and downstream end of the treatment, air temperature, channel width, depth, gradient, and elevation.

Sampling Frequency: Data should be collected each summer for two years prior to the treatment (if possible) and for two years after, and then at two to three year intervals until the riparian stand stabilizes or meets management system shade requirements. Thereafter, monitor after major disturbances.

Evaluation Procedure: Effectiveness will be evaluated by applying two criteria: 1) was there an increase in stream temperature associated with practice (temperature higher at downstream end of treated site), and 2) were the state water quality criteria and/or management system targets met?

Question F. What factors influence riparian practice and restoration measure effectiveness and how can their effectiveness be improved?

Monitoring Approach: In addition to evaluating effectiveness, it is also important to determine which factors influence effectiveness. To address this issue, stand condition data collected for questions A and B need to be interpreted in the context of practice types, site conditions, and other factors of interest. Stratifying monitoring sites by situational categories (described below) allows harvest practices or restoration measures implemented in a variety of site conditions to be compared to determine how effectiveness varies. Additional data also need to be collected on changes in stand condition brought about by specific factors of interest, such as sun scald, windthrow, and animal damage. In order to determine which factors contributed to effectiveness, sites with different responses to each factor can be compared. For example, sites in three different soil condition categories can be compared to determine if soil condition influences effectiveness.

Question G. What factors influence riparian stand growth, mortality, and the recruitment, persistence, routing and function of LWD in stream channels?

Monitoring Approach: To answer this question, it will be necessary to collect long-term data sets on tree growth, tree mortality, and LWD recruitment processes in riparian stands, and persistence, routing, and function of LWD in stream channels in various regions throughout Washington State. This information will be valuable for improving the accuracy of LWD recruitment modeling efforts, improving the LWD targets used for evaluating effectiveness, and interpreting the results of effectiveness monitoring projects.

2.3 DESIGNING TFW MONITORING PROJECTS

This section discusses how to use the information on program goals, objectives, and monitoring questions presented in the section 2.1 to design TFW monitoring projects to evaluate riparian forest practice and restoration measure effectiveness, and to document the design in a monitoring plan.

2.3.1 Identifying the Monitoring Project Objective(s)

The first step in designing a TFW effectiveness monitoring project is to identify which objective(s) the project will address. Projects should address the goal and at least one of the objectives in section 2.1.2 below in order to contribute information on the effectiveness of riparian practices or restoration measures needed by the TFW Effectiveness Monitoring and Evaluation Program. The next step is to develop specific project objectives and document them in the monitoring plan. Monitoring project objectives can be derived directly from one of the more general objectives, but should identify the types of practices/restoration measures that will be examined and the location. Some examples of monitoring project objectives are:

- To evaluate the effectiveness of Watershed Analysis riparian prescriptions in the Salmon Creek WAU in producing stand conditions at harvest sites that provide adequate levels of LWD and associated functions over time.
- To evaluate the influence of windthrow on the effectiveness of two types of riparian prescriptions in the Salmon Creek WAU.
- To evaluate the effectiveness of the riparian restoration practice (alder removal and conifer planting) in reducing maximum stream temperatures and increasing LWD recruitment in the Southwest Cascades eco-region.
- To determine the dominant causes of mortality and the rates of tree growth and LWD recruitment in managed and unmanaged riparian stands in northwestern Washington.

2.3.2 Developing Project-Specific Monitoring Questions and Hypotheses

After determining the objectives of the monitoring project, the next step is to identify specific monitoring questions that need to be answered to meet the objectives. Review Table 1 for a list monitoring questions that can be addressed in the site-scale evaluation, the data needed to answer them, and criteria for evaluating effectiveness. Select one or more monitoring question(s) you wish to address.

After the appropriate questions are identified, they should be refined to accomplish the specific objectives of the project. A hypothesis should be developed for each question that includes a prediction for success or failure, and describes the expected influence of factors that may affect the outcome. Hypotheses must also be testable, which means they can be accepted or rejected based on the monitoring data that are collected. Monitoring questions and hypotheses should be documented in the monitoring plan. Examples are provided below:

- **Monitoring Question A:** Do the riparian LWD prescriptions in the Salmon Creek WAU produce riparian stand conditions that meet management system targets for riparian stand conditions?
  <u>Hypothesis</u>: The riparian prescriptions will produce stand conditions that meet or exceed the prescription targets, in terms of species, density, and size class of trees for the first decade after harvest.
  Monitoring Questions B and C: Are the riparian LWD prescriptions for the Salmon Creek WAU effective at providing LWD recruitment and adequate levels of in-channel LWD and associated pools over the long-term?

  <u>Hypothesis</u>: Adequate amounts of functional LWD will be recruited from these riparian stands to continue to produce sufficient pools for good coho rearing habitat, as defined the Watershed Analysis manual.

  Monitoring Questions D: Are the riparian shade prescriptions for Geomorphic Unit 3 in the Salmon Creek WAU effective at providing adequate shade to meet the shade requirements in the Forest Practice Board Manual?
  <u>Hypothesis</u>: The prescriptions will provide adequate shade to meet or exceed the shade requirements in the Forest Practices Board manual immediately after harvest and over time.

- **Monitoring Question (E):** Do the riparian prescriptions in the Salmon Creek WAU provide adequate shade over time to avoid increases in stream temperature?
  <u>Hypothesis</u>: No increase in stream temperature will occur as the stream moves through the treatment reach and state water quality standard for stream temperature will be met or exceeded.

- **Monitoring Question (F):** Does windthrow influence the effectiveness of “no-cut 20-m buffer” and “partial-cut 30-m buffer” riparian prescriptions in the Salmon Creek WAU? Do channel size, channel orientation, and clear cut size influence the effects of windthrow for these two prescriptions?
  <u>Hypothesis</u>: Windthrow will reduce the density of trees below the targets in the Watershed Analysis prescriptions in the Salmon Creek WAU where riparian stands are harvested with “no-cut 20-m buffers,” but not for those harvested with “partial-cut 30-m buffers.” Channel size, channel orientation, and clear cut size do not alter the effects of windthrow on tree density.

After generating specific monitoring questions and hypothesis for the project, the next step is to clearly document the procedure for evaluating effectiveness in the monitoring plan. The recommended evaluation approaches for each monitoring question are described in section 2.2 above. Monitoring projects can address several questions with one data collection effort.

Projects that evaluate effectiveness (question A-E) are encouraged to also collect information on factors that influence effectiveness (question F), so that recommendations can be made for improvements to riparian forest practices and restoration measures.

2.3.3 Sampling Design and Procedures

After identifying the relevant monitoring questions, testable hypotheses, and a procedure for evaluating effectiveness, the next step is to develop a sampling design. To do this, it is necessary to establish a stratification scheme for monitoring sites, develop a procedure for selecting sites, identify parameters that need to be measured at each site, and determine the frequency at which sites will be monitored over time. Guidelines for completing these tasks are provided below.

2.3.3.1 Stratification of Sampling Sites

Monitoring sites need to be stratified by situational categories and other factors of interest. Stratification is a tool used to address variability and improve interpretation of results by placing sites into categories based on similar characteristics. Situational categories reflect a combination of practice types and site conditions that serve to stratify monitoring sites at a coarse level. This system helps organize sites for analysis, increases comparability between monitoring projects conducted throughout the state, and guides the extrapolation of results to similar situations. For these reasons, all monitoring sites must be classified by the situational categories in Table 3.

Table 3. Situational categories for riparian harvest practices and restoration measures

Practice Type	
1. Harvest Practices	RMZ total width: 0-10 m, 10-20 m, 20-30 m, >30 m
	RMZ no-cut width: 0-10 m, 10-20 m, 20-30 m, >30 m
2. Restoration Practices	thinning, plant conifers
Riparian Stand and Stream Characteristics	
Physiographic region	nine regions throughout the state
Site productivity	high, moderate, low
Initial Stand condition	6 categories based on stand composition, size and density
Stream gradient	0-1%, 1-2%, 2-4%, 4-8%, 8-20%, >20%
Channel confinement	confined, moderately confined, unconfined
Stream size (bankfull width)	<3 m, 3-10 m, ≥10 m
Stream elevation	0-1000 ft, 1-2000 ft, 2-3000 ft, > 3000 ft

Monitoring projects may use these situational categories to identify appropriate sampling sites. For this purpose, one or more situational categories should be selected, and monitoring sites should be randomly chosen from all streams that fall into those categories. Other projects may select a single site of interest, all of the sites that come up for harvest, or use some other system for selecting sites not based on situational categories. For these projects, it is still necessary to determine the situational category for each site after it is selected.

In addition to situational categories, it may be desirable to stratify sites by other factors to help answer a specific monitoring question. For example, sites could be stratified by three different sizes of clear cut to evaluate the effects of clear cut size on windthrow in RMZs. These optional strata should be directly related to a specific hypothesis and clearly outlined in the monitoring plan. Regardless of the strata used, all sites must still be categorized by situational category.

2.3.3.2 Site Selection

Once the situational categories and other factors that will be used for stratification are selected, the next step will be to select sites. Typically, this will involve identifying all of the sites within the watershed or region of interest that fall into the monitoring strata that were selected. If it is not possible to monitor all sites in a stratum of interest, a procedure to select a sample of sites should be developed in consultation with a statistician experienced in sampling design. Site selection procedures and sampling plans must be thoroughly documented in the monitoring plan.

2.3.3.3 Monitoring Parameters and Methods

After developing a system for stratifying and selecting sampling sites, the next step is to choose appropriate parameters. Table 4 lists the parameters that need to be measured for each monitoring question and the appropriate data collection methods. Additional parameters may be measured to help answer specific monitoring questions, and should be thoroughly described in the monitoring plan.

For results to be comparable between projects, it is essential that all monitoring projects use comparable, standard methods. The specific methods for each parameter is are listed in Table 4. Methods for measuring riparian stand parameters described in the TFW Effectiveness Monitoring Program Riparian Stand Survey (Smith 1998). The TFW Stream segment Identification Module (Pleus and Schuett-Hames 1998) is used to document channel characteristics such as channel gradient, confinement and elevation. The TFW Monitoring LWD Level Two Survey (Schuett-Hames et al. 1994) should be used for collecting LWD data and the TFW Stream Temperature Survey (Rashin et. al 1994) should be used to collect stream temperature and canopy closure information. All of the riparian stand parameters and some of the stream channel parameters will be collected in several sampling plots placed systematically at each site. Additionally, individual trees and LWD pieces may be tagged to monitor LWD recruitment and routing processes over time.

2.3.3.4 Monitoring Frequency

The final step in developing a sampling design is to establish the frequency that monitoring parameters need to be collected over time. Monitoring before the harvest practice or restoration activity occurs would be ideal for establishing a baseline that can be used to document changes brought about directly by the treatment. Some of this information can also be partially reconstructed after the treatment by recording information on stumps and recent windthrow. Sites should also be sampled immediately after the treatment to determine if they comply with management system prescriptions or restoration objectives. Sites not in compliance should not be included in effectiveness monitoring projects because they are likely to confound the results.

For harvested sites, monitoring every two to five years within the first decade will capture disturbances to the RMZ from windthrow, sun scald, or other harvest-related stressors (monitoring question A). Thereafter, monitoring at 5 or 10 year intervals over the long-term will document how stand condition, LWD recruitment and in-channel LWD, and associated functions

Table 4. Minimum parameters that need to be measured to answer various monitoring questions

Parameter	Applicable Monitoring Question							Method
	A	B	C	D	E	F	G	
Riparian Stand Parameters								
species, diameter, condition, landform, and distance from stream for standing trees	X	X	X	X	X	X	X	TFW Riparian Stand Survey[1]
number and species of tree seedlings/saplings	X*	X	X	X	X	X*	X	TFW Riparian Stand Survey[1]
site productivity	X	X	X	X	X	X*	X	TFW Riparian Stand Survey[1]
species, azimuth of fall, decay class, diameter, and zone of influence of down wood	X*	X	X	X	X	X	X	TFW Riparian Stand Survey[1]
age, height, and density of the stand	X	X	X	X	X	X	X	TFW Riparian Stand Survey[1]
area of the RMZ or restoration site	X	X	X	X	X	X	X	TFW Riparian Stand Survey[1]
Channel Parameters								
Stressors: harvest-related (e.g. windthrow or sun scald) or restoration-related, (e.g. animal damage or understory competition)	X	X	X	X	X	X	X	TFW Riparian Stand Survey[1]
canopy closure				X	X	X*	X	TFW Stream Temp. Survey[2]
channel gradient and confinement		X	X	X	X	X	X	TFW Segment ID Procedure[3]
stream elevation				X	X			TFW Segment ID Procedure[3]
stream size (based on bankfull width or stream order)			X	X	X	X*	X	TFW Reference Point Survey[4]
Resource Condition Parameters								
LWD characteristics (number, species, volume)			X			X*	X	TFW LWD Survey[5]
LWD function (pools, sediment storage, cover)			X			X*	X	TFW LWD Survey[5]
water and air temperature					X			TFW Stream Temp. Survey[2]

* These parameters may be optional, depending on the objectives of the monitoring project
[1] TFW Riparian Stand Survey (Smith, 1998)
[2] TFW Stream Temperature Survey (Rashin et al., 1994)
[3] TFW Stream Segment Identification Module (Pleus and Schuett-Hames, 1998)
[4] TFW Reference Point Survey (Pleus and Schuett-Hames, 1998)
[5] TFW LWD Survey (Schuett-Hames et al., 1994)

change over time (monitoring questions B and C). These data can also be used to validate predictions of the LWD recruitment model and to determine factors that influence effectiveness of riparian harvest practices (monitoring questions F and G). For monitoring shade and stream temperature, the pre-harvest baseline should be at least two years to document temperatures under a range of streamflow and air temperature regimes. Monitoring should occur annually for two years after harvest, and at intervals thereafter determined by changes in, or disturbance to, the riparian stand.

For restoration measures, stand condition will need to be monitored at least every year following the restoration to evaluate whether the short-term objectives of the restoration are achieved, and to identify factors that influence effectiveness, such as animal damage and understory competition. Overstory vegetation characteristics may not need to be measured for a number of years, while rapid changes in the understory will require frequent and intensive sampling. It will also be necessary to document ongoing efforts to make the restoration successful, such as fertilization, brush control, and animal damage control.

If the restoration measure completely fails to achieve its short-term objectives (for example, conifer seedlings are out-competed by salmonberry), it would be considered ineffective, and no further monitoring would be needed. If the restoration measure is at least partially successful in the short-term, then monitoring should occur at five or ten year intervals to document how stand condition, in-channel LWD, and associated functions change over time.

2.3.3.5 Training and Quality Assurance

The TFW Monitoring Program provides methods training and quality assurance services for monitoring projects that have successfully completed the sampling design review process. This helps to ensure that the monitoring methods are applied consistently, the data are reliable and results are comparable between projects.

2.4 DATA ANALYSIS AND INTERPRETATION

The final step in designing a monitoring project is to determine how data collected in the project will be analyzed, interpreted, archived, and reported. The analysis process needs to be directly linked to the monitoring hypotheses and the procedure for evaluating effectiveness. It should be clearly documented in the monitoring plan.

Analysis of site-scale effectiveness monitoring information has two parts. The first step is to evaluate each individual site or practice. The second is to aggregate the results of groups of similar practices that occur in similar situations (situational categories) so that conclusions can be drawn about the effectiveness of various types practices under different conditions.

The following two sections provide guidance in data analysis and interpretation individual practices (2.4.1) and groups of practices (2.4.2).

2.4.1 Analysis and interpretation of individual practice effectiveness

To answer question A (how do riparian stand composition and condition change following the riparian practice or restoration measure?), data from each riparian stand survey collected at various times after the treatment must be compared with the appropriate target established by the management system (Watershed Analysis, Habitat Conservation Plan or Landowner Landscape Plan prescription or forest practices rules). Riparian LWD targets vary but are typically expressed as a leave tree count (trees per acre or trees per lineal distance of stream). In some cases the leave trees must meet criteria for species (e.g. conifer/deciduous), size (diameter), age, or dominance. Consequently, data must be analyzed and compiled specifically for the pertinent management system target.

To answer question B (how do recruitment potential and LWD recruitment rates from the riparian stand change over time following the riparian practice or restoration measure?), data from each riparian stand analyzed to determine recruitment potential; i.e., the number of trees of sufficient height to potentially reach the channel and of sufficient size to function in the channel.

All trees where height exceeds distance from the stream are considered to be potentially recruitable to the channel. Of the potentially recruitable trees, only those that would meet the volume criteria for key pieces in the Watershed Analysis fish habitat resource condition indices when they entered the channel are considered to be of sufficient size to provide functional LWD. Recruitment potential is expressed in terms of trees potentially providing functional LWD per lineal distance of stream. Recruitment rates and processes are also derived from the stand data by tallying the number and volume trees that fall into the channel in a given time period for each recruitment process and recruitment type class. Recruitment rate is expressed as the number and volume of trees entering the channel per lineal distance of stream/year. To determine practice effectiveness, data on recruitment potential and recruitment rate from the treated stand is the compared with reference stand data from unmanaged stands with similar site conditions to estimate the effect of the practice on LWD recruitment potential and recruitment rates. Effectiveness for recruitment potential and recruitment rate is reported as a percentage of that of the comparable unmanaged stand. Information on the relative significance of various recruitment processes is analyzed by determining recruitment rates for each recruitment processes and comparing the rates for each process in the treated and unmanaged stands to identify differences.

To answer the portion of question C (how does the abundance and characteristics of in-channel LWD pieces and the functions they provide change over time?) related to LWD abundance and characteristics, data on in-channel LWD pieces is processed by the TFW Monitoring Program database to determine the total pieces and key pieces per channel width, and volume per channel width by piece size category and channel location. This information can be compared with data from earlier surveys to determine trends, and trend information can be compared with model projections done with prior data to validate predictions. Trend information can also be compared with data from appropriate reference stands to determine how the number and volume of pieces within the treatment reach compare with similar unmanaged conditions. To answer the portion of question C related to LWD function, the number and characteristics of pieces performing in-channel functions including pool formation and sediment storage should be calculated for each survey, and compared with data from earlier surveys to determine trends over time.

Management system shade requirements are expressed in terms of a target level for percentage of canopy closure. To answer question D (how does the shade provided by the riparian stand change over time following the riparian practice or restoration measure?), data on canopy closure should be used to calculate mean canopy closure for the treatment reach. The current value for mean canopy closure should be compared with past values to document trends and with the shade requirements of the management system and the forest practices board manual (WFPB, 1995b).

To answer question E (how does the maximum stream temperature regime change over time in response to the riparian practice or restoration measure?), stream and air temperature data should be analyzed to determine maximum stream temperatures and instances when the appropriate water quality standards for the stream reach are exceeded. Trends can be determined by comparing daily, weekly, and monthly maximum temperatures, and number of days water quality standards are exceed, with the results of previous surveys. However, differences in stream temperature between survey years must be interpreted in the context of differences in air temperature regimes between the survey years.

To answer question F (what factors influence riparian practice and restoration measure effectiveness and how can their effectiveness be improved?), data on stand condition and recruitment potential, recruitment rates and processes must be analyzed to determine why each practice is, or is not effective. Trend information from the treatment, output from riparian growth and yield models, and comparisons with reference stands can be used to determine whether the practice was effective or not. Examples of questions that should be examined include:

- were stocking levels adequate following the practice or restoration measure? Why?
- did excessive mortality occur before the trees became tall enough to reach the stream or large enough to function? Was it due to natural or harvest-related causes?
- how did the mortality/recruitment processes differ from those observed in comparable reference stands? Why?

To answer question G (what factors influence riparian stand growth, mortality, and the recruitment, persistence, routing and function of LWD in stream channels?), long-term data sets from monitoring sites will be analyzed to determine growth rates, mortality rates and causes, recruitment rates and processes, and LWD loss in both managed and reference stands. This information will be used to evaluate riparian stand growth, mortality and LWD recruitment models, and will provide the opportunity to calibrate models for local or regional conditions.

2.4.2 Analysis and interpretation of practices by situational category

To evaluate performance by situational category, the results of the individual practices should be compiled by situational category and expressed as a frequency distribution. For example, if a particular type of riparian practice is monitored at 16 sites and produces results at 12 sites that are deemed effective, the practice is characterized as effective in 75% of the cases. Further analysis is required to determine the factors that cause the practices to be ineffective by examining the results of question F. For example, a practice may be ineffective in cases where the stand contains a large percentage of deciduous trees, or at sites where windthrow occurs after harvest. The final step is to develop recommendations for improving practices in situations where they are ineffective. Detailed hypotheses and a good stratification scheme will make this process simpler. For example, hypotheses that include testing several different types of practices for the same set of site conditions allow conclusions to be drawn about which practice was most effective in each site condition. Or, a careful examination of site conditions might reveal which sites are most prone to windthrow, and recommendations could be made to reduce windthrow on those types of sites. If improvements are not suggested by the analysis, then it may be necessary to develop a more specific hypothesis about the cause of ineffectiveness, and collect additional data on the sites where the practices were ineffective or to test alternate practices for difficult site conditions.

2.5 MONITORING PROJECT REVIEW

Study designs for monitoring projects developed using these guidelines should be documented in a monitoring plan submitted to the CMER Monitoring Advisory Group for review to ensure the project meets the objectives of the TFW Effectiveness Monitoring and Evaluation Program.

3. EVALUATING EFFECTIVENESS OF FOREST MANAGEMENT SYSTEMS IN PROTECTING AND RESTORING RIPARIAN FUNCTIONS ON A WATERSHED-SCALE

Forest management systems protect and restore riparian stands and functions by guiding how (and to some extent when) forest practices and restoration practices are conducted in and around riparian stands on forest lands in order to maintain or create stand conditions that achieve aquatic resource protection objectives such as providing large woody debris (LWD) recruitment and shade to regulate summer stream temperatures. As multiple practices occur over time, the management system has a profound influence on riparian disturbance and recovery processes and the condition of riparian stands on a watershed. This section (Section 3) of the document provides guidelines for designing monitoring projects to evaluate the effectiveness of forest management systems in producing riparian stand conditions that provide adequate LWD recruitment and shade to protect or restore aquatic resources on a watershed scale. The applicable management systems for state and private lands addressed by the TFW Effectiveness Monitoring and Evaluation Program are Watershed Analysis (WSA), Habitat Conservation Plans (HCPs), Landowner Landscape Plans (LLPs), and the State forest practices rules.

These guidelines can be used to design projects that address riparian LWD recruitment and shade separately or simultaneously. Steps in the study design process include identifying the project goals objectives, determining the monitoring questions the project will address, developing testable hypotheses, documenting the procedure for evaluating effectiveness, creating a sampling design, documenting monitoring and data analysis methods, and submitting the monitoring plan for review. These steps are described below.

3.1 TFW GOAL, OBJECTIVES, AND ASSUMPTIONS

The TFW Effectiveness Monitoring and Evaluation Program goal and objectives for evaluating the effectiveness of forest management systems in protecting and restoring riparian functions on a watershed scale are based on the more general goals outlined in the TFW Effectiveness Monitoring and Evaluation Plan (Schuett-Hames et al. 1998, sec 2.4). Projects designed using these guidelines should address the program goal and at least one of the program objectives in order to contribute information needed by TFW cooperators and the TFW Effectiveness Monitoring and Evaluation Program to evaluate and improve the effectiveness of forest management systems in protecting and restoring riparian functions.

3.1.1 TFW Goal

To support adaptive management by evaluating the effectiveness of forest management systems in protecting and restoring riparian stands that provide adequate LWD recruitment and shade to protect aquatic resources on a watershed scale.

3.1.2 TFW Objectives

1. To evaluate the effective of multiple riparian forest practices and restoration projects carried out under forest management systems in providing adequate LWD recruitment and associated functions over time at a watershed scale.

2. To evaluate the effective of multiple riparian forest practices and restoration projects carried out under forest management systems in producing riparian stands that provide adequate shade levels to maintain or restore summer stream temperature regimes suitable for aquatic resources throughout the watershed.
3. To evaluate factors that influence the effectiveness of forest management systems in protecting and maintaining riparian functions in order to identify improvements in situations where they are ineffective.
4. To improve interpretation of monitoring results by collecting data on the rates and factors controlling various LWD recruitment processes and the persistence, routing, and function of LWD at a watershed scale.

3.1.3 Assumptions

Several assumptions are required to answer the effectiveness monitoring questions using the guidelines described in this document.

1. Forest practices (and restoration measures) affect LWD recruitment and stream temperature regimes by altering number and type of trees in riparian stands due to harvest of trees, silvicultural practices, and triggering mass wasting.
2. Changes in the amount of shade and LWD recruitment potential of riparian stands can be accurately estimated from aerial photographs.

3.2 TFW MONITORING QUESTIONS AND EVALUATION PROCEDURE

This section presents a list of effectiveness monitoring questions that are designed to focus monitoring efforts to provide information needed by the TFW Effectiveness Monitoring and Evaluation Program. The discussion also covers the data needed to answer each question and the TFW approach for using that information to evaluate effectiveness.

Table 5 lists monitoring questions to that must be answered to determine the effectiveness of forest management systems in maintaining the riparian functions of LWD recruitment and shade over time on a watershed scale. Each question is designed to address the program objectives and provide answers to effectiveness questions of concern to TFW. Some of these monitoring questions involve effectiveness monitoring to address the effects of forest management systems on riparian stand conditions relative to LWD recruitment potential (Question A) and shade (Question C). Other monitoring questions involve complementary validation monitoring to determine the in-channel response of LWD function (Question B) and stream temperature (Question D) to forest management on a watershed scale. Question E involves monitoring to determine the causal linkages between management systems and stand conditions and provides information needed to improve management system performance. Question F involves validation monitoring/research to improve our understanding of LWD recruitment and routing on a watershed scale. Monitoring projects sponsored by the TFW Monitoring Advisory Group will be designed to answer these questions. TFW cooperators are encouraged to undertake monitoring that will contribute information to help answer these questions on a regional or statewide level, or to adapt these monitoring questions to address local issues. Table 5 also lists the data required and the evaluation procedures used to answer each question.

Table 5. Monitoring questions related to the effectiveness of forest management systems in protecting and restoring riparian functions on a watershed scale.

Monitoring Question	Monitoring Type	Data Required	Evaluation Procedures
A. Do forest management systems produce riparian stand conditions that provide adequate LWD recruitment potential over time on a watershed scale?	Effectiveness Monitoring (LWD Recruitment).	WSA riparian stand condition classes (based on dominant vegetation, tree size and stand density from aerial photography).	Riparian stands will be given a recruitment potential rating of low, moderate or high using the rating system in the WSA Riparian Function Assessment (WFPB, 1995a). Current data (latest available aerial photography) will be compared with historic to determine changes in LWD recruitment potential by stream segment type.
B. How does LWD abundance and function respond to forest management systems over time on a watershed scale?	Validation Monitoring (LWD Resource Response).	Data on in-channel LWD abundance, volume, characteristics, and function.	Current LWD conditions (abundance, volume, and function) will be compared with baseline information (if available) to determine trends, and will be rated as good, fair or poor using the WSA resource condition indices for debris pieces and key pieces (WFPB, 1995a).
C. Do forest management systems produce riparian stand conditions that provide adequate shade over time on a watershed scale?	Effectiveness Monitoring (Riparian Shade).	Estimated percentage of canopy closure (based on aerial photography).	Current shade levels for riparian stands (based on latest available aerial photography) will be compared with historic shade levels to determine changes and compared with target shade levels for forest streams (WFPB, 1995b).
D. How do summer stream temperatures respond to forest management systems over time on a watershed scale?	Validation Monitoring (Stream Temperature Response).	Data on maximum stream temperatures, canopy closure, air temperature and channel morphology.	Data on current maximum stream temperatures will be compared with baseline information (if available) to determine trends. Temperatures in all reaches will be compared with state water quality standards.
E. What factors influence the effectiveness of forest management systems in protecting and restoring riparian functions, and how can they be improved?	Effectiveness Monitoring (LWD recruitment and shade).	Factors affecting riparian stands where LWD recruitment potential and shade decrease below targets or fail to recover as expected.	Information will be used to identify factors that influence effectiveness and to develop recommendations to improve practices.
F. What are the rates and dominant factors influencing recruitment, persistence, routing, and function of LWD in forested watersheds?	Validation Monitoring (LWD).	Rates and mechanisms of LWD recruitment, transport and decay on a watershed scale.	None proposed.

The monitoring approach, data requirements, sampling frequency and evaluation procedures for each monitoring question listed in Table 5 are described individually below. Monitoring projects may be designed to address several questions with one data collection effort. Projects that evaluate effectiveness (questions A-D) should also consider collecting information on factors that influence effectiveness (question F), so that recommendations can be made to improve forest management systems.

Question A. Do forest management systems produce riparian stand conditions that provide adequate LWD recruitment potential over time on a watershed scale?)

Monitoring Approach: Answering this question involves monitoring changes in the LWD recruitment potential of riparian stands managed under each management system in the watershed.

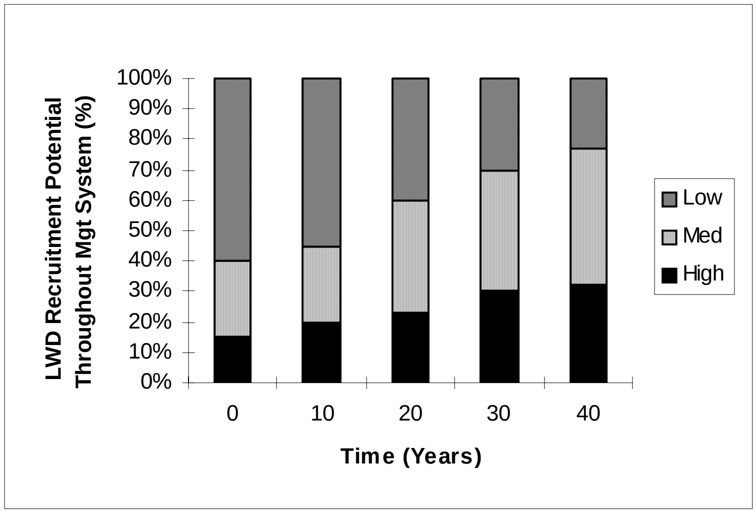
Data Requirements: Stream length in WSA riparian recruitment stand condition classes (based on dominant vegetation type, tree size class, and stand density) and short-term LWD recruitment potential for all streams in the watershed with gradients equal to or less than 20 percent by management system and stream gradient/confinement category.

Sampling Frequency: To develop the trend data needed to answer this question, it will be necessary to document riparian stand conditions over time. Sampling frequency will depend upon the availability of aerial photography coverage for the watershed. Historic aerial photo should be used to document trends up to the current time.

Evaluation: In order to be considered effective, a management system should produce and maintain riparian stands that have high recruitment potential. Many riparian stands harvested under previous management systems currently have low or medium recruitment potential, and will require many years to improve after a new management system is implemented. In this situation, the management system should prevent any reduction in recruitment potential, and there should be a trend towards increased recruitment potential as low or medium riparian stands grow and increase in recruitment potential over time. Figure 1 shows an example of a trend in stand conditions moving toward high LWD recruitment potential. The management system should be considered effective if the majority of riparian stands reach this condition and a full rotation of harvest activities does not significantly reduce recruitment potential.

Due to the long time frame before it is possible to determine effectiveness of a management system, individual riparian stands where harvests take place (not including restoration projects) should be monitored to detect potential problems early on. This can be accomplished with field sampling using the methods for the site-scale riparian evaluation or with the methods described in this document. If harvest activity reduces LWD recruitment potential at a site, then the management system should be considered ineffective for that site. It is important to keep track of these individual activities because natural growth in unharvested riparian stands may increase overall LWD recruitment potential while young stands mature, and then recruitment potential may abruptly decline throughout the watershed when these stands are harvested.

Figure 1. Trend toward increasing LWD recruitment potential of riparian stands managed under a single management system.



Question B. How does LWD abundance and function respond to forest management system on a watershed scale over time?)

<u>Monitoring Approach</u>: Answering this monitoring question requires data on changes in-channel LWD collected on a watershed scale to evaluate the cumulative effect of multiple forest practices on aquatic resources over time. Unfortunately, associating LWD levels to a particular management system is problematic because LWD recruitment and routing processes are not fully understood, so further work is needed in this area. A project is currently being conducted that will provide guidance for stratifying and selecting stream segments to characterize changes in LWD loading and function on a watershed scale.

<u>Data Needed</u>: Data on in-channel LWD abundance, volume, characteristics and function from a sample of stream segments (less than or equal to 20 % gradient) stratified by gradient confinement class and management system.

<u>Sampling Frequency</u>: Sampling needs to occur once every five to ten years or after major disturbance events (e.g. fire, flood or windstorms).

<u>Evaluation Procedure</u>: Data on LWD abundance, volume, function collected during iterative surveys will be compared with baseline information to determine trends in over time. Data on LWD abundance will also be compared with WSA resource condition indices for debris pieces and key pieces to determine the WSA rating (WFPB, 1995a).

Question C. Do forest management systems produce riparian stand conditions that provide adequate shade over time on a watershed scale?

<u>Monitoring Approach</u>: Answering this question involves monitoring changes in the canopy closure of riparian stands managed under each management system in the watershed.

<u>Data Requirements</u>: Shade levels for riparian stands (estimated percentage from aerial photography).

<u>Sampling Frequency</u>: To develop the trend data needed to answer this question, it will be

necessary to monitor riparian stand conditions at five to ten year intervals. This should be adequate to document changes in the shade provided by riparian stands, however accelerated natural or anthropogenic disturbance would warrant a more frequent sampling interval (depending on the availability of aerial photographs).

Evaluation Procedure: In order to be considered effective, management systems should produce and maintain riparian stands that provide adequate shade to maintain summer stream temperatures required to meet water quality standards (WFPB, 1995b). Riparian stands harvested under previous management systems may not have shade, and will require years to improve after a new management system is implemented. In this situation, the management system is effective if it prevents further reduction in shade, and produces a trend towards increased shade as riparian stands grow and shade increases over time.

Question D. How do summer stream temperatures respond to forest management systems over time on a watershed scale?

Monitoring Approach: Answering this question requires monitoring of summer stream temperatures on a watershed scale to evaluate the effect of multiple forest practices on aquatic resources over time. Stream segments in the WAU likely to respond to changes in riparian canopy closure will be identified and stratified on the basis of elevation, channel width and gradient, and data will be collected from a sample of segments from each strata. Reaches with known temperature problems will also be sampled.

Data Requirements: Data on maximum stream temperatures, canopy closure, air temperature and channel morphology are needed.

Sampling Frequency: Two consecutive years of data is needed to establish baseline conditions. Sampling should occur at five to ten year intervals thereafter.

Evaluation Procedure: Data on current maximum stream temperatures will be compared with baseline information to determine trends after screening to insure that seasonal air temperature and discharge regimes are comparable. Maximum temperatures should decrease (move towards meeting water quality standards) adjacent to stands where riparian shade is increasing as stands grow following previous harvest and remain the same (or decrease) in areas where stands are mature. Temperatures in all reaches will be compared with state water quality standards.

Question E. What factors influence the effectiveness of forest management systems in protecting and restoring riparian functions, and how can they be improved?

Monitoring Approach: To answer this question, riparian stands in the WAU should be stratified by situational categories (described below). Stands where LWD recruitment potential or shade levels have declined or failed to recover as expected should be identified. Riparian stands that have declined or remained low in recruitment potential over time should be examined on air photos or visited in the field to determine the cause. In cases where LWD recruitment potential or shade have decreased due to management activity, or stands with low recruitment potential or inadequate shade are failing to recover, improvements in the management system that would provide needed protection or encourage recovery should be identified. Restoration activities that attempt to convert hardwood stands to conifers may reduce recruitment potential in the short-term, but should improve recruitment potential in the long-term. Riparian stands that have a naturally low recruitment potential (such as hardwood-dominated stands in frequently flooded areas) or that have declined in recruitment potential due to natural disturbance do not indicate that the management system is ineffective.

Question F. What are the rates and dominant factors influencing recruitment, persistence, routing, and function of LWD in forested watersheds? No guidance for answering this question is provided in this document, however projects that generate information about processes influencing LWD recruitment and function at a watershed scale are needed for improving the interpretation of monitoring results.

3.3 DESIGNING TFW MONITORING PROJECTS

This section discusses how to use the information on program goals, objectives, and monitoring questions presented in the sections 3.1 and 3.2 to design TFW monitoring projects to evaluate the effectiveness of forest management systems in protecting and restoring riparian functions on a watershed-scale, and to document the design in a monitoring plan. The section discusses identifying project -specific monitoring objectives, determining monitoring questions and hypotheses, and developing a sampling design and sampling procedures.

3.3.1 Identifying The Monitoring Project Objectives

The first step in designing a TFW effectiveness monitoring project is to identify which objective(s) the project will address. Projects should address the goal and at least one of the objectives in section 2.1.2 below in order to contribute information on the effectiveness of riparian practices or restoration measures needed by the TFW Effectiveness Monitoring and Evaluation Program. The next step is to develop specific project objectives and document them in the monitoring plan. Monitoring project objectives can be derived directly from one of the more general objectives by refining the program objectives into detailed project-specific objectives. Monitoring project objectives should identify the management system(s), watershed or region, and effectiveness monitoring issues of interest, and should be clearly documented in the monitoring plan. Some examples of monitoring project objectives are:

- **Example Project Objective (LWD):** To evaluate the effectiveness of Watershed Analysis in providing adequate levels of LWD and associated functions over time throughout the Salmon Creek Watershed Administrative Unit (WAU).
- **Example Project Objective (TEMP):** To evaluate the effectiveness of Watershed Analysis in providing adequate levels of shade for Type 3 waters at elevations less than 1000 feet in the Salmon Creek WAU.

3.3.2 Developing Project-Specific Monitoring Questions and Hypotheses

After the objectives have been identified for the monitoring project, refine the effectiveness monitoring questions to accomplish those objectives. Then, use the effectiveness evaluation criteria selected to develop null hypotheses to answer each question. Null hypotheses must be testable, which means they can be accepted or rejected based on the monitoring information that is collected. Developing good hypotheses is very important for designing successful effectiveness monitoring projects because they determine the type of monitoring data that will be collected and indicate how those data will be used to answer effectiveness monitoring questions. Example monitoring questions and corresponding hypotheses are provided below:

- **Example Monitoring Question:** Did Watershed Analysis produce riparian stands in the Salmon Creek WAU that provide high LWD recruitment potential?

Null Hypothesis: Stands with initially low and medium LWD recruitment potential managed under the Salmon Creek Watershed Analysis have no significant increase in recruitment potential after 10 years.

- **Example Monitoring Question:** Will implementation of the Salmon Creek Watershed Analysis result in shade levels that meet forest practices regulation targets in Type 3 waters at elevations less than 1000 feet?

  Null Hypothesis: The estimated mean canopy closure for Type 3 waters at elevations less than 1000 feet in the Salmon Creek WAU will equal the target value in the Forest Practices Board manual.

3.3.3 Sampling Design

After developing hypotheses, the next step is to develop a sampling design to test the hypotheses and apply the appropriate evaluation procedures to determine effectiveness. To do this, it is necessary to select watersheds for monitoring, stratify each watershed, identify parameters that need to be measured throughout each watershed, and determine the frequency for monitoring. Then document the sampling design in the monitoring plan. Guidelines for completing these tasks are provided below.

3.3.4 Watershed Selection

For watershed-scale monitoring, Watershed Administrative Units (WAUs) are the basic sampling units. These units should not be subdivided, but can be aggregated to form larger watersheds. Watersheds should be selected for monitoring based on the objectives of the monitoring project, which in many cases will be a single watershed. If more than one watershed will be monitored, however, the approach for selecting them should be described in the monitoring plan. Each watershed needs to be placed into a situational category based on physiographic region and geologic conditions so that monitoring results can be extrapolated to watersheds that have similar characteristics. This statewide stratification system is currently being developed, and will soon be available as a separate document.

3.3.5 Watershed-scale Stratification

Each watershed selected for monitoring needs to be delineated into stream segments, and each stream segment needs to placed into a situational category based on the management system and site condition categories in Table 6. This will provide information on how site conditions influence the effectiveness of various management systems in each watershed. Stream segments should be associated with a management system based on the present jurisdiction, regardless of past practices that may have influenced stand conditions. For example, when a Watershed Analysis is completed in a WAU, then it becomes the management system for all forest lands under its jurisdiction, even where specific prescriptions have not yet been implemented. If the Watershed Analysis defers to standard rules in some areas, those areas are still managed by the Watershed Analysis. If a watershed has competing management systems, such as when HCP boundaries partially overlap with a Watershed Analysis, riparian stands should be associated with the management system most likely to guide forest practices at each site, which is generally the most protective one. Federal forest lands are easily determined on the basis of ownership. Urban, agricultural, and other non-forest land uses are not considered under the jurisdiction of a forest management system. Riparian stand condition should still be evaluated in these areas, however, for comparison purposes and to provide a complete picture of conditions throughout a watershed.

To answer questions A and/or C, the riparian stand condition and or shade level needs to be determined for all stream segments with gradients ≤ 20%. If optional LWD or temperature data are collected (monitoring questions B and/or D), then the strategy for selecting sampling sites should be described in the monitoring plan (e.g. will sampling occur throughout the watershed, in randomly chosen stream segments, or only in a few important stream segments?).

Table 6. Situational categories for delineating watersheds into stream segments

Management System:	State and private forest lands - Watershed Analysis - Habitat Conservation Plan - Landowner Landscape Plan - Standard rules - Other management system Federal forest lands Non-forest lands
Channel Gradient:	0-1%, 1-2%, 2-4%, 4-8%, 8-20%
Channel Confinement:	Unconfined, Moderately confined, Confined

3.4 SAMPLING PROCEDURES

After a proposed sampling design has completed the review process, it should be ready for implementation. This section describes the sampling procedures that the monitoring project should use, including monitoring methods, training, and quality assurance. A detailed description of the procedures should be described in the monitoring plan.

3.4.1 Monitoring Methods

For results to be comparable between projects, it is essential that all monitoring projects use the same methods. For question A, aerial photographs should be used to characterize riparian stand conditions using the methods described for the Watershed Analysis Riparian Function Assessment (Washington Forest Practices Board 1995a). If not already completed for Watershed Analysis or some other purpose, watersheds should be delineated into stream segments using the TFW Stream Segment Identification Method (Pleus and Schuett-Hames 1998). If LWD data are being collected to answer question B, the TFW Large Woody Debris Survey (Schuett-Hames et al. 1994) should be used. To produce the data needed to answer question C, aerial photographs should be used to estimate canopy closure and field verified using the methods described in the Watershed Analysis Riparian Function Assessment (Washington Forest Practices Board 1995a). To collect the data needed to answer question D, the methods described in the TFW Stream Temperature Survey (Rashin et al. 1994) should be used.

3.4.2 Training and Quality Assurance

A plan for training and quality assurance should also be included in the monitoring plan. The TFW Monitoring Program can provide methods training and quality assurance services for monitoring projects that have successfully completed the sampling design review process. The Washington Department of Natural Resources provides training and certification for the Watershed Analysis Riparian Assessment. These training programs help to ensure that monitoring results are comparable between projects.

3.5 DATA ANALYSIS

The final step in designing a monitoring project is to describe how data collected in the project will be analyzed. The analysis process needs to be directly linked to the monitoring hypotheses and the criteria for evaluating effectiveness, and should be clearly documented in the monitoring plan.

3.5.1 Riparian LWD recruitment potential and in-channel LWD

The results of the aerial photograph analysis should be presented to indicate the percentage of riparian stands in each LWD recruitment potential category for the various management systems in the watershed (Table 7). For each management system of interest, LWD recruitment potential percentages should also be broken down by situational categories to indicate differences in LWD recruitment potential by channel type. If data was collected on in-channel LWD abundance, volume and function it should be presented, and the analysis could examine correlation's between LWD abundance, recruitment potential, channel type, historical land use, and management system.

Table 7. Example of LWD recruitment potential for all segments in a watershed by management system type.

Management System	**LWD Recruitment Potential**									**Total Stream Miles**
	High			**Medium**			**Low**			
	Stream Miles	% Mgt System	% of WAU	Stream Miles	% Mgt System	% of WAU	Stream Miles	% Mgt System	% of WAU	
Watershed Analysis	10	25%	13%	10	25%	13%	20	50%	25%	40
Forest Service	5	25%	6%	10	50%	13%	5	25%	6%	20
Agriculture	0	0%	0%	5	25%	6%	15	75%	19%	20
Total for WAU	15		19%	25		31%	40		50%	80

If all of the riparian stands have high recruitment potential except those with naturally low recruitment potential or that have been recently affected by a natural disturbance, then the management system should be considered potentially effective. It should be considered fully effective if it maintains high recruitment potential after a full rotation of harvest activity. For management systems that have not yet achieved high recruitment potential, it will be necessary to look at trends over time. In order to establish a statistical trend in LWD recruitment potential throughout the watershed, data are needed from at least three different years. Plot the percent of stream length with high recruitment potential for each year and fit a line to the points. If the slope of the line is positive and significantly different from zero, then the management system should be considered potentially effective; otherwise it should be considered ineffective.

Data should be presented for all riparian stands where harvests have taken place under the management system, including stream miles affected and the stand condition before and after the harvest. The management system should be considered ineffective at sites where harvest has reduced LWD recruitment potential. Calculate the total harvested stream miles and the percentage of that total where harvest has reduced recruitment potential. If this percentage is large, it is likely that the management system will be considered ineffective overall as more harvest activities take place, so recommendations should be made for improving practices as soon as possible. Harvests intended to restore conifers to a hardwood-dominated stand should be tracked separately.

For all riparian stands that have declined or remained low in recruitment potential over time, data should be presented on stream miles affected and probable cause. These should be sorted by situational categories to illustrate the influence of site conditions. Specific categories of riparian stands could be compared statistically to test monitoring project hypotheses. This information can also be used to improve interpretation of results about management system effectiveness. If necessary, recommendations should be made to improve practices or actively restore riparian stands to improve LWD recruitment potential.

3.5.2 Riparian canopy closure and summer stream temperature

A similar analysis similar to that described above should also be done with shade and stream temperature data collected to answer questions C and D. The total stream length meeting canopy closure targets should be calculated for each management system represented in the watershed. The percentage of stream miles meeting shade targets should also be calculated by situational categories (gradient/confinement, channel width and elevation) to identify situations where the management systems are not effective in providing shade. If data was collected on summer stream temperatures, it should be analyzed to identify maximum temperatures and days when water quality was exceeded. The analysis should also examine correlation’s between maximum stream temperatures and shade levels, stand conditions, channel width and gradient, current and historical land use, and management system.

3.6 MONITORING PROJECT REVIEW

Monitoring plans developed using these guidelines should be submitted to the CMER Monitoring Advisory Group for review. Specific criteria for this review process are still being developed, but the intent is to ensure that monitoring projects meet the overall goals and objectives of the TFW Monitoring and Evaluation Program. Additionally, the TFW Monitoring Program can provide technical assistance at any stage in the monitoring project design and implementation process.

References

Bilby, R.E. and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society. 118:368-378.

Kennard, P., G. Pess, T. Beechie, B. Bilby, and D. Berg. 1997. Riparian-in-a-box: a manager's tool to predict the impacts of riparian management on fish habitat. In press.

Pleus, A. E. and D. Schuett-Hames. 1998. TFW Monitoring Program method manual for stream segment identification. Washington Department of Natural Resources. Olympia, WA.

Pleus, A.E. and D. Schuett-Hames. 1998. TFW Monitoring Program method manual for the reference point survey. Washington Department of Natural Resources. Olympia, WA.

Rashin, E., D. Schuett-Hames, J. Matthews and A. Pleus. 1994. Timber-Fish-Wildlife Ambient Monitoring Program Stream Temperature Module. *In:* D. Schuett-Hames, A. Pleus, L. Bullchild, and S. Hall eds. Ambient Monitoring Program Manual. Washington Department of Natural Resources, Olympia, WA.

Schuett-Hames, D., K. Lautz, J. Light, R. McIntosh, D. Smith, N. Sturhan, K. Sullivan, and G. Wilhere. 1998. TFW effectiveness monitoring and evaluation program plan. Washington Department of Natural Resources, Olympia, WA.

Schuett-Hames, D., J. Ward, M. Fox, A. Pleus, and J. Light. 1994. Large woody debris survey module. *In:* D. Schuett-Hames, A. Pleus, L. Bullchild, and S. Hall eds. Ambient Monitoring Program Manual. Washington Department of Natural Resources, Olympia, WA.

Smith, D. 1998. Riparian stand survey. Review draft. Northwest Indian Fisheries Commission, Olympia, WA.

Washington Forest Practices Board. 1995a. Standard methodology for conducting watershed analysis, v. 3.0. Washington Department Natural Resources, Olympia, WA.

Washington Forest Practices Board. 1995b. Forest Practices Board Manual: method for determination of adequate shade requirements on streams. Washington Department Natural Resources, Olympia, WA.