Effectiveness of Forest Road and Timber Harvest BMPs with Respect to Sediment-related Water Quality Impacts

Progress Report

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INTRODUCTION

This study to evaluate the effectiveness of certain forest road and timber harvest best management practices (BMPs) is being conducted by the Department of Ecology as a part of the Timber/Fish/Wildlife Cooperative Monitoring, Evaluation and Research Program (CMER). The project is sponsored by CMER's Water Quality Steering Committee (WQSC), and is funded jointly by CMER, the Department of Ecology, and the U.S. Environmental Protection Agency. Objectives of the project are: 1) to gather qualitative and quantitative information on BMP effectiveness by monitoring representative examples of BMP implementation; 2) to develop and apply criteria for determining whether water quality standards are met where forest practice-related sediment impacts are concerned; 3) to evaluate and describe the factors influencing BMP effectiveness; and 4) to determine whether certain BMPs require modifications in order to achieve water quality standards, and recommend such changes.

The purpose of this Progress Report is: 1) to report on progress to date on the project, describe the study sites established, and discuss survey methodologies employed; 2) to describe study site selection criteria; and 3) to present a preliminary assessment of the sampling design. It was originally planned that this progress report would be prepared at the conclusion of the pilot phase. However, because of a delay in starting, the pilot phase of the project will continue through November of 1992.

PROGRESS TO DATE

The project study plan was approved by CMER on April 20, 1992 following peer review and a TFW technical workshop (Rashin, 1992). An inter-agency agreement providing CMER funding was signed May 20, 1992. Work on the project began in earnest in late July, when the first of two project-funded staff started, although preliminary site screening and other preparations had been underway since May. By August 5 we were fully staffed, had selected our first candidate study sites, and were defining our field protocols. We have since made numerous field reconnaissance visits to candidate study sites, using a standardized reconnaissance protocol. Our main priorities during the first two months of the pilot phase of the project have been the selection of study sites and the development and testing of field survey methodologies.

Selection of Study Sites

To date we have selected 12 study sites at which we will evaluate 27 examples of specific BMP implementation. Study site locations and physiographic regions are shown in Figure 1. Table 1 summarizes study site information according to the sample stratification scheme outlined in the project study plan. This scheme calls for examples of BMP implementation to be grouped into BMP categories, with the sample stratified by physiographic regions and by landscape hazard within each region. We have categorized all BMP examples as either harvesting, new road construction, or road maintenance. Within these categories, we have identified "specific BMPs," which are actually groupings of closely related practices as outlined in the Washington Forest Practices Rules and Regulations (Title 222 WAC). Thus, each study site has one or more specific BMP examples to be evaluated, and each specific BMP example may represent one or more practices, as specified in the individual WAC paragraphs.

The 27 BMP examples selected to date include 11 harvesting BMPs (tractor/wheeled skidding, Riparian Management Zones, and Type IV Riparian Leave Tree Areas), 15 new road construction BMPs (road drainage design, culvert installation, and construction techniques), and one road maintenance BMP (active haul road maintenance). Four physiographic regions of the state are represented in the sample so far.

Development and Testing of Survey Methodologies

In addition to selecting study sites, our main emphasis during the pilot phase has been on the development and testing of field survey methodologies. The project team has held a series of focused work sessions to discuss options for survey techniques. At these work sessions we discussed protocols as well as the working assumptions on which surveys are based, the sensitivity of the methods, and the hypotheses to be tested. Table 2 is a matrix that shows the surveys conducted or planned for each of the study sites and specific BMP examples. The methods are summarized in Appendix A in terms of their objectives. Some of the methods covered in Appendix A are not shown in Table 2, because they are not currently planned for these study sites. Although it is not the purpose of this progress report to provide detailed descriptions of survey methods, some of our key methods are discussed briefly below.

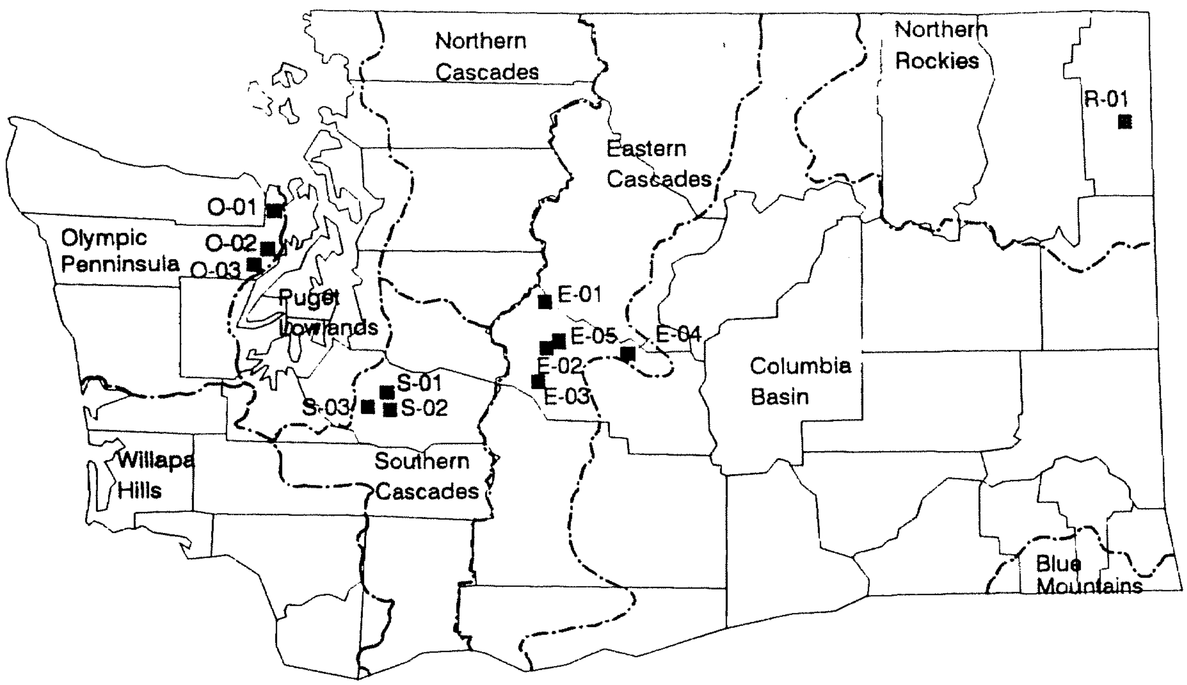

Figure 1: Physiographic Regions and Study Site Locations

TABLE 1: STUDY SITE INFORMATION

PHYSIOGRAPHIC REGION	SITE ID #	BMP CATEGORY EVALUATED	SPECIFIC BMP	SLOPE HAZARD CLASS
Olympic Peninsula	O-01	Harvesting	RMZ	Low
		Harvesting	Tractor\Wheeled Skidding	Low
	O-02	Harvesting	Type IV RLTA	Moderate
		Harvesting	Tractor\Wheeled Skidding	Moderate
	O-03	New Road Constr.	Road Drainage Design	Moderate
		New Road Constr.	Culvert Installation	Moderate
		New Road Constr.	Construction Techniques	Moderate
Eastern Cascades	E-01	New Road Constr.	Culvert Installation	Moderate
		New Road Constr.	Road Drainage Design	Moderate
	E-02	New Road Constr.	Road Drainage Design	Moderate
		New Road Constr.	Culvert Installation	Moderate
		New Road Constr.	Construction Techniques	Moderate
	E-03	Harvesting	Type IV RLTA	Moderate
		New Road Constr.	Construction Techniques	Moderate
	E-04	Harvesting	Tractor\Wheeled Skidding	Moderate\High
	E-05	Harvesting	Tractor\Wheeled Skidding	Low
Southern Cascades	S-01	Road Maintenance	Active Haul Road	Low
	S-02	New Road Constr.	Road Drainage Design	High
		New Road Constr.	Culvert Installation	High
		New Road Constr.	Construction Techniques	High
		Harvesting	RMZ	High
		Harvesting	Tractor\Wheeled Skidding	High
	S-03	New Road Constr.	Road Drainage Design	High
		New Road Constr.	Culvert Installation	High
Northern Rockies	R-01	New Road Constr.	Culvert Installation	Moderate
		Harvesting	Tractor\Wheeled Skidding	Moderate
		Harvesting	RMZ	Moderate

Table 2: Study Site Survey Matrix*

Site ID #	Specific BMP Evaluated	Channel Condition Survey	Photo Point Network	Stream Features Survey	Channel Substrate Transects	Erosion Pin/Bridge Network	Erosion/ Sediment Routing	Road/Skid Tr. Run-Off Sampling	Road Surface Condition	Culvert Condition Survey	Zero-Order Basin Survey	Sequential Aerial Photos	Road Drainage Mapping
O-01	RMZ			P								C	
	Tractor/Wheeled Skidding					P	P	P				C	
O-02	Type IV RLTA	C	C	P	C							C	
	Tractor/Wheeled Skidding	C	C		C	P	P	P				C	
O-03	Road Drainage Design	C	P	P	P		P	P	P			C	P
	Culvert Installation	C	P	P	P					P		C	P
	Contruction Techniques	C	P	P	P		P	P	P			C	
E-01	Culvert Installation	C	C	C									P
	Road Drainage Design	C	C	C									P
E-02	Road Drainage Design	P	C	P		C	P	P	P	C	C	P	P
	Culvert Installation	P	P	P	P					P			P
	Construction Techniques	P	P	P	P	P							
E-03	Type IV RLTA	P	C	P	P		P					P	
	Construction Techniques	P					P	P	P				
E-04	Tractor/Wheeled Skidding	P	P			P	P	P				P	
E-05	Tractor/Wheeled Skidding		P				P	P	P			P	
S-01	Active Haul Road Maintenance	P	P		P		P	P	P	P			P
S-02	Drainage Design	P	P	P			P		P	P	P		P
	Culvert Installation	P	P	P			P		P	P	P		P
	Construction Techniques	P	P	P	P	P							
	RMZ	P		P	P								
	Tractor/Wheeled Skidding		P				P		P				
S-03	Road Drainage Design	P	P	P		P	P	P		P			P
	Culvert Installation	P				P	P	P	P				P
R-01	Culvert Installation		P							P		P	P
	Tractor/Wheeled Skidding	P	P	P		P	P	P	P	P	P	P	
	RMZ	P	P	P	P							P	

* C=Surveys Conducted; P=Surveys Planned; See Appendix A for additional survey methodologies not yet conducted or planned for these sites.

Among the methods developed and tested to date are qualitative channel condition surveys, which will be performed on most study sites. These surveys document the status of such processes as bank erosion, sediment deposition, and overall channel stability, and are sensitive to detecting gross changes in these conditions. They also serve to describe and classify the stream channel morphology and evaluate the similarity between stream reaches downstream of BMPs and control reaches. Another commonly used method is the photo-point survey, which we use to document the conditions of stream channels and specific features within channels (eroding banks, storage structures, sediment wedges and bars, etc.), road cuts and ditches, and culverts. The establishment of permanent photo-points and use of scaled photos, including stereo pairs, will allow us to estimate the dimensions of key features and evaluate changes over time. Sequential photography of the same photo-points will allow comparisons before and after significant hydrologic events.

The qualitative channel condition surveys and photo-point surveys will be used in conjunction with survey techniques that are sensitive to more subtle changes in erosion and sediment deposition. These include the stream features survey and channel substrate transects. In the stream features survey we identify specific erosion or deposition features within the study reach, such as cut banks and sediment wedges or bars. Individual examples of these features will be measured over time to compare the change in erosion and/or deposition between downstream and control reaches. The channel substrate transects subsample the streambed within study reaches, documenting the extent of surface fines, level of embeddedness, and the dominant and subdominant particle size. The study reach is first mapped according to "functional units", with segments classified as predominantly erosional, depositional, or transport units. The depositional units are then subsampled, using a modification of the transect sampling method described in Torquemada and Platts (1988).

SITE SELECTION CRITERIA

Study site selection for the project generally begins by screening Forest Practices Applications (FPAs) submitted to Ecology Regional Offices for road building and ground-based harvesting practices conducted near streams. Additionally, examples of road maintenance BMPs are identified through discussions with land owners and other cooperators. Potential study sites are also identified through pre-harvest review documents prepared by forest land owners. We then discard any FPAs which do not identify any type I-V waters within or adjacent to the operational boundary. Initially screened and accepted FPAs are organized according to landowner and physiographic region. We then contact the landowner, usually by phone. Landowners willing to participate in the study are asked a series of questions regarding operation timing, accuracy of water type maps, and access problems.

After identifying potential study sites within a physiographic region, a field reconnaissance survey is conducted. Typically, an integral part of the field survey is a meeting with the landowner to facilitate information exchange and logistics. After landowner consultation, the unit is "reconned" for acceptance as a study site.

Acceptance of a candidate site involves three primary criteria: timing, isolation, and control availability. Timing generally refers to the actual operation in relation to a major hydrologic event. Because we want to document conditions before a significant hydrologic event has occurred, we discard operations which occurred before a runoff-producing rain storm, rain-on-snow event, or spring thaw. Another consideration is the timing of the forest practice operation in relation to our initial surveys. For some BMPs it is preferable to conduct preliminary surveys before the practice is conducted. On the other hand, for many of the BMPs and survey techniques it is preferable or necessary to have the practice on the ground before we begin our surveys. For example, when evaluating culvert installations, road ditch or cutbank erosion, or skid trail erosion, conditions existing in upland areas before the practice are not as important as being able to observe the exact location of the practice, and conditions in stream channels will not be impacted until a significant hydrologic event occurs. At this point, we have encountered only one unit on which some minor erosion and sediment transfer from the road surface and cut slopes was evident in deposition areas near culvert outfalls. However, there was no evidence of sediment transport or runoff downstream of the immediate outfall area at this site, so it was judged an acceptable site.

The isolation criterion refers to land use patterns and the ability to separate the effects of the BMP from cumulative effects of other logging practices, and other land use interferences such as grazing and mining. We discard sites which demonstrate substantial impacts from these other land uses--a particular concern in eastern Washington. The location and timing of other forest practice activities are considered in deciding whether we can isolate the targeted BMP. An upstream/downstream sampling design, looking primarily at near-field indicators of BMP effectiveness, generally allows us to isolate site specific examples of the practice.

The third criterion involves the availability of a "control" site, usually a stream reach immediately upstream from the BMP. Off-site reaches used as controls must have similar geomorphologic and hydrologic characteristics. Sites lacking suitable controls are discarded. Potential study sites satisfying the three criteria are accepted.

Our experience during the pilot phase of the study has shown that most landowners constructed their roads and began harvesting as early as possible this summer in anticipation of operational closures due to fire danger. Also, we have found that with many landowners, the FPA is not available for screening very far in advance of the operation. This situation, coupled with our late start this field season, allowed for very few surveys to be conducted before the practice was conducted. However, given current weather patterns, we anticipate three to six more weeks of dry weather surveys on the sites we have currently selected. In terms of future site selection, we expect to concentrate our efforts during the winter on the Willapa Hills physiographic region and other lower elevation parts of western Washington where winter operations will occur. We may also select a few more sites in the Northern Rockies region this fall. During the late spring and early summer of 1993 we will again be actively screening FPAs and pre-harvest reviews to select our remaining study sites.

The project study plan calls for the sample, grouped according to general BMP categories, to be stratified according to physiographic regions and relative hazard classes. As stated in the study plan, experience gained during the pilot phase will be used as a reality check to refine the scope of the project. The study plan included a map of physiographic regions compiled by Pentec (1991), a landscape hazard classification scheme, and a table listing various high and low priority BMPs to sample. At this point in the pilot phase, we are prepared to make changes in 1) the regional stratification scheme, 2) the hazard classification scheme, and 3) the list of BMPs to sample.

Regional Stratification

The map of physiographic regions, shown in Figure 1, is slightly modified from that given in the study plan. We have changed the boundaries between the Northern Rockies (referred to as the Okanogan Highlands in the Pentec map), Eastern Cascades, and Columbia Basin to reflect the ecoregion boundaries given in Omernik and Gallant (1986). We have also revised the boundary between the Willapa Hills and Southern Cascades regions to better reflect similarities in surface geology, soils, and pleistocene glaciation effects.

Perhaps more significant than these changes in regional boundaries are our decisions about the statewide scope of the project. We will not be sampling within three of the nine physiographic regions: Columbia Basin, Blue Mountains, and Puget Lowlands. The Columbia Basin is an obvious choice for exclusion because it has very little commercial forest land. A limited amount of state or privately owned forest land is found in the Blue Mountains region, and we have screened and reconned some FPAs there. However, we chose to exclude this region because interferences from past logging and grazing practices appear to be rather widespread, and the distance from our base of operations is considerable. Also, we believe that many of our observations made in other regions of eastern Washington will be applicable to BMP effectiveness in the Blue Mountains region. Finally, we have excluded the Puget Lowlands because of the need to further narrow our focus and because of our perception that land use conversion plans may affect BMP implementation on many of the forest practice operations in this region.

We plan to distribute our sample over the remaining six regions according to the approximate proportions of FPAs submitted for these regions. We have used the Forest Practice Program 1991 Calendar Year Report (Department of Natural Resources, 1992) as a guide to this distribution. We made several assumptions about distribution within the DNR regions, since their regional boundaries did not correspond with our physiographic regions. We assumed that the 1991 distribution of Class III and Class III Priority FPAs approximates the distribution of BMPs we seek to sample. Based on the statistics summarized in the report, we plan to distribute our total sample (defined by the number of specific BMP examples we survey) as shown in Figure 2.

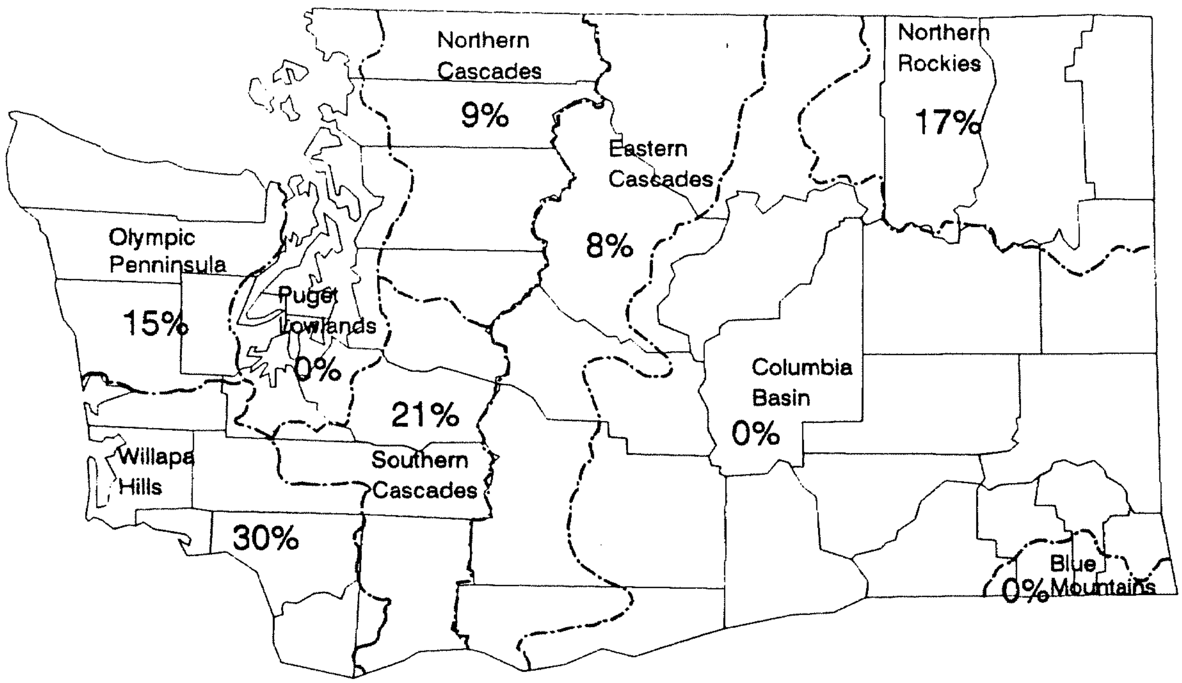

Figure 2: Sample Distribution According to Physiographic Region

Hazard Classification

For purposes of sample stratification, we have simplified the landscape hazard classification scheme presented in the study plan. We now identify High, Moderate, and Low hazard classes based solely on slope angle. The former scheme incorporated slope form and rain-on-snow hydrology as modifiers to the slope hazard. While we acknowledge that these as well as other factors influence the inherent landscape hazard, we believe that it is most appropriate to evaluate their influence on a case by case basis. For purposes of ensuring that our sample is distributed across varying degrees of inherent hazard, we will use the unmodified slope hazard class. We believe slope angle is the primary controlling factor, and one that can be objectively defined and determined on-site from easily obtained field measurements. While we have simplified the scheme in terms of the factors considered, we have decided to have separate slope hazard classification schemes for harvesting and road-related BMPs. We have done this because of a difference in the relative dominance of erosion processes; surface erosion may be a more dominant process for harvest practices such as skidding, whereas mass wasting processes may be more important for road construction and maintenance. The new scheme is presented in Table 3.

TABLE 3: SLOPE HAZARD CLASSIFICATION
(For Purposes of Sample Stratification)

BMP Category	LOW	MODERATE	HIGH
Harvesting BMPs	0-19% slope	20-40% slope	>40% slope
New Road Construction & Road Maintenance BMPs	0-19% slope	20-50% slope	>50% slope

We believe that our process of screening large groups of FPAs within a region and considering all potential study sites (*i.e.*, practices in the vicinity of streams) will result in a sample that reflects the distribution of targeted BMPs across the three slope hazard classes.

BMPs Under Consideration

The study plan included a table that lists BMPs grouped according to "Higher Priority" and "Lower Priority." We have decided not to actively pursue examples of most of the "Lower Priority" BMPs, which include site preparation, cable yarding, slash disposal, and landing location/construction practices. While these practices are important, we believe it is necessary to focus our sample on the higher priority BMPs, all of which are included in our "specific BMPs" listed in Tables 1 and 2. However, while we will not focus our efforts on the lower priority BMPs, we may obtain some information on their effectiveness coincidental with our surveys of higher priority practices. BMPs for maintenance of inactive and abandoned roads, included on the "Lower Priority" list in the study plan, are still being considered for inclusion in the study. Determining the effectiveness of these BMPs is important because inactive and abandoned roads have been identified as sources of debris flows (Pentec, 1991). However, as with other road maintenance BMPs, compliance with applicable regulations has been shown to be lacking in many cases (TFW Field Implementation Committee, 1991), so we must carefully select examples that are compliant in order to assess BMP effectiveness.

In order to stratify our sample and focus our efforts in a deliberate way, we suggest targeting a proportion of the total number of BMP examples to each BMP category. The priorities for addressing sediment-related water quality impacts, based on our literature review and discussion with field personnel, suggest focusing about 40% of our sample on harvest BMPs, 40% on new road construction, and 20% on road maintenance. Feedback from the WQSC and others on this proposed distribution would be helpful. It was stated in the study plan that we would evaluate about 100 examples of BMP evaluation. Our current expectation is that we will have a total sample size of 40 to 60 BMP examples. However, as mentioned earlier, each of our BMP examples may represent more than one individual BMP as specified in the regulation.

Representativeness of Sampling Design

We are using a case study approach to evaluate the effectiveness of targeted BMPs. We believe that our sample will be representative of statewide BMP implementation because of our sample stratification scheme--i.e., we are evaluating *typical* BMPs implemented under varying degrees of inherent landscape hazard in different physiographic regions of the state. We expect to have several examples within each of these strata, with the distribution among strata determined by the distribution of FPAs submitted within the various regions. The selection of samples is not technically random, because of our site selection criteria. However, it is random in the sense that we generally begin with a large stack of recently approved FPAs, and our screening process eliminates only those which obviously do not meet our criteria. All others are considered as potential sites. We believe our case study approach will achieve the project objectives. We will gather information on the effectiveness of BMPs implemented in a variety of settings, allowing us to assess a gradient of BMP effectiveness and to describe various factors influencing effectiveness.

It has been suggested that we consider taking a statistical approach to establishing our sample size for this study. Under this approach, the total number of BMP examples evaluated would be based on an assumed statistical distribution of the entire population, and on desired levels of precision and accuracy that describe how well the sample results represent the entire population. A key to this approach is describing the size of the sampled population. Although we could start by looking at the number of FPAs from the 1991 Forest Practices Program report, we would have to make several rather tenuous assumptions to define the number of the specific BMPs we are targeting. For example, a certain percentage of these FPAs are for BMPs we are not sampling (forest chemicals, cable logging, etc.), while a certain percentage cover multiple target BMPs under a single FPA. Other assumptions would have to be made about the percentage of

FPAs which have no water near the unit. Also, we would have to define the number of road maintenance BMPs that are not included in the number of FPAs. Given the nature of assumptions that would have to be made, we do not believe it is feasible to define the population of targeted BMPs in a meaningful way.

The primary benefit which could be gained by using a statistical approach to determining our sample size would be the ability to describe how well the percentage of effective BMPs in our sample represents the percentage of effective BMPs in the entire population. A statistically designed sample size would not increase the confidence in any of our individual BMP effectiveness "calls," nor would it increase our ability to meet project objectives. Also, because of the large number of assumptions we would have to make regarding the entire population of BMPs, a statistical design would not ensure that we have defined the representativeness of our sample. Our case study approach, based on a deliberate stratification of our sample to evaluate representative BMP implementation scenarios, does not rely on such assumptions about the entire population of BMPs. Each case study is representative of other similar BMP implementation scenarios.

Application of the Scientific Method

We are deliberately applying fundamental aspects of the scientific method to our study design. In the development of our survey methodologies we identify key assumptions that we rely on and outline the hypotheses we are testing. The fundamental assumptions we rely on deal with the erosion and sedimentation processes which may be affected by forest practices, tests of BMP effectiveness, and the sensitivity of various monitoring methods. Our key working assumptions may be summarized as follows:

- Certain forest practices have the potential to accelerate erosion processes, and sediment from such accelerated erosion may be delivered to streams and other waterbodies where it may be deposited and/or transported downstream. While erosion and sedimentation may be accelerated by forest practices, they also occur as natural processes.

- The best management practices we are testing are intended to ensure that water quality standards are met by controlling erosion and sediment delivery to waterbodies, and protecting the integrity of streams with respect to erosion and sedimentation.

- Accelerated erosion and sediment deposition and transport in streams, when caused by forest practices and other human activities, may violate state water quality standards, particularly where existing or potential beneficial uses of surface waters are adversely affected. Aquatic life uses are particularly sensitive to erosion and sedimentation, and the water quality standards require protection of the most sensitive species and communities. Achievement of the water quality standards is the primary test of BMP effectiveness.

- Monitoring techniques differ in their sensitivity to detecting accelerated erosion and sediment deposition and transport. Some techniques are only sensitive to gross changes in erosion and sedimentation rates, while others are more sensitive to subtle changes.

We have summarized key hypotheses we are testing in the matrix presented in Appendix B. The hypotheses are organized by BMP, with surveys methods useful in testing each hypothesis indicated. These hypotheses address BMP effectiveness from the standpoint of what each BMP is designed to accomplish.

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APPENDIX A: Objectives for Survey Methods Under Consideration

1) Channel Condition Survey: A qualitative assessment of a stream reach which characterizes channel morphology, hydrologic regimes, and the current status of channel/bank erosion and sediment deposition based primarily on visual estimates and rapid field measurements.

   * To describe channel morphology and streambed and bank characteristics, and overall channel stability.
   * To document the current status of erosion and deposition processes.
   * To assess the similarity of downstream study reaches and control reaches.

2) Photo-Point Network: The establishment of permanent reference photo-points for sequential photography, including scaled photos and oblique angle stereo pairs.

   * To document the status (including approximate dimensions) of features of stream channels, road prisms, culverts, skid trails, etc., in order to allow an assessment of change over time.

3) Stream Features Survey: Individual erosional and depositional features within study reaches, such as cut banks, sediment wedges, and bars, are identified, mapped and subsampled by measuring their physical dimensions and photo documentation.

   * To measure the number, surface area, and volume of storage structures, sediment deposits and/or erosional features downstream of a forest practice, and compare the rate of change in these features to changes in similar features within an upstream or other control reach.

4) Channel Substrate Transects: Depositional units within study reaches are identified, mapped and subsampled by ocular estimates and/or hoop sampling along transects, using modifications of techniques described in Torquemada and Platts (1988).

   * To evaluate change in surface substrate composition, surface accumulation of fines, and cobble embeddedness by sampling depositional units downstream of a forest practice and comparing the rate of change to an upstream or other control reach.

5) Erosion Pin/Bridge Network: A network of erosion pins and/or erosion bridges is established on portions of skid trails, road cuts and/or fills, road ditches, or stream banks, and sequential measurements are made to document the change in elevation of the soil surface.

   * To determine whether measurable surface erosion is occurring at a site with exposed soils.
   * To obtain an estimate of the volume of material displaced from an area of exposed soil.
   * To obtain an approximate rate of change for soil erosion and streambank erosion.

6) Erosion Mapping/Sediment Routing: Following the forest practice, skid trails, roads and erosional features such as gullies and landslides are mapped using aerial photography and/or ground surveys. Routes of sediment transport and sediment storage sites are mapped and monitored to assess delivery to surface waters.

* To map and monitor changes in sediment source areas and sediment storage sites.
* To identify sediment routing pathways and assess delivery to surface waters.

7) Road/Skid Trail Run-off Sampling: Water samples of run-off from streams above and below BMPs, road ditches, and other drainage pathways are collected during runoff events and analyzed for turbidity and total suspended solids. Discharge and precipitation are monitored concurrently.

* To assess fine sediment loading from road surfaces and other disturbed areas.
* To assess turbidity and suspended sediment loads in streams above and below road crossings and other practices during storm events.

8) Road Surface Condition Survey: Active haul road surfaces are evaluated during wet weather conditions to observe and measure gravel depth, thickness of fines, rutting, and drainage conditions. Often done in conjunction with runoff sampling. Information on road traffic and maintenance history is related to observations.

* To evaluate the adequacy of road surface and drainage maintenance on active haul roads during wet weather conditions, and relate surface conditions to fine sediment in runoff.
* To determine whether maintenance BMPs are preventing excessive fine sediment loading to streams, and preventing drainage-related slope failures.

9) Qualitative Culvert Condition Surveys: Newly installed or existing culverts or are monitored for effectiveness of armoring, and overall stability using photo point networks.

* To evaluate the integrity culverts, particularly outflow and inflow armoring over the study period, and assess the overall stability of stream crossings.

10) Zero-Order Basin Surveys: Zero-order basins, also known as headwalls or channel initiation points, are monitored for changes in morphology and channel head migration following the BMP to be evaluated--typically road construction above the basin. Photo point networks are established and topographic surveys are used to monitor changes in the size and location of channel heads, and to assess mass wasting processes.

* To monitor changes in size, location, and condition of channel heads and other zero-order basins features following BMP implementation.

11) Sequential Aerial Photography: Low altitude, large scale aerial photographs are obtained for selected BMP sites. Custom photography is flown by the Department of Transportation. Photos are scaled by measuring actual distances of fixed points on the ground within units. After scaling, erosion features, channel heads, and other features are mapped and evaluated using GIS techniques. Sequential photography is used to document changes in erosion features, etc. over time.

* To examine large-scale landscape features that may influence the stability of the study reach, control reach, etc.;
* To measure the area disturbed by a forest practice;
* To aid in the mapping and display of erosion and sediment routing surveys.

12) Road Drainage Mapping: Changes in the drainage area of small streams or zero-order basins are evaluated by mapping the road-induced drainage pattern and road surface area and comparing this to the original, natural drainage patterns. Used in conjunction with zero-order basin surveys, runoff sampling, and other surveys.

* To provide a basis for evaluating the effectiveness of road drainage design BMPs as they affect the processes of surface erosion and mass wasting.

13) Fine Sediment Pool Filling Survey: Residual pool depth and pool volume (V*) techniques developed by Lisle and Hilton (1991) are employed to measure the amount of fine sediment deposited in pools following high flow events, upstream and downstream of BMPs.

* To evaluate changes in the deposition of fine sediment in pools downstream of a forest practice, and compare to changes in pools upstream of the practice.

14) Macroinvertebrate Sampling: Aquatic macroinvertebrate populations and community structures are evaluated using modified techniques from the Environmental Protection Agency's Rapid Bioassessment Protocols. Sampling is conducted upstream and downstream of BMPs, and the results are used in conjunction with other survey results to evaluate changes in the macroinvertebrate community. Sampling results are also compared to reference site conditions as reported by Plotnikoff (1992).

* To evaluate changes in habitat conditions, macroinvertebrate populations, and community structures within study and control reaches selected to monitor the effectiveness of BMPs at preventing adverse impacts to resident biota.

15) Amphibian Sampling: Sampling techniques developed by Bury and Corn (1991) for monitoring responses of headwater habitats, stream amphibian populations, and community structure following logging are employed to evaluate changes following BMPs implementation.

* To evaluate changes in amphibian populations, community structures, and habitat condition following BMP implementation, and compare results to control reaches.

16) Sidecast Construction Overburden Surveys: Volumes of sidecast construction overburden are estimated using rod, tape, and level surveying techniques established at transects along the forest road being evaluated. Changes in the volume of material are monitored.

* To measure the amount of material placed on a hillslope at an angle steeper than what was occurring at the site prior to road construction, and the angle, volume, and degree of change in these features over the study period.

APPENDIX B: Hypotheses Framework for Sediment BMP Study

BMP Category	Hypothesis to be Tested	Surveys to Consider
New Road Construction		
A) Road Drainage Design WAC 222-24-025 (5)-(9)	A1) The expanded drainage area and other hydrologic changes caused by the road may change the erosive energy of runoff causing accelerated bank/channel erosion in stream reaches below road crossings.	-Photo Point surveys -Channel Condition Surveys -Stream Features Surveys -Channel Substrate Transects -Erosion Pin/Bridge Networks -Road Drainage Mapping -Sequential Aerial Photography -Macroinvertebrate Surveys -Amphibian Surveys
	A2) The expanded drainage area and other hydrologic changes caused by road construction may result in mass wasting or other erosion in small stream channels or zero-order basins.	Same as for Hypothesis A1 plus: -Zero-Order Basin Surveys
	A3) BMP specifications result in adequate drainage relief (i.e. dissipation of runoff volume/energy), such that drainage from new road construction will not result in accelerated streambank erosion or mass wasting that degrades aquatic habitats or negatively affects other water uses.	Same as for Hypotheses A1 & A2
B) Culvert Installation and Temporary Stream Crossings WAC 222-24-040 (2)-(4)	B1) BMP specifications result in culverts that are adequately sized and culvert installations that are adequately stabilized and armored, such that "blowouts" will not occur and stream banks and channels will not be subject to accelerated erosion and sediment deposition that degrades aquatic habitats or negatively affects other water uses.	-Culvert Condition Surveys -Channel Condition Surveys -Photo Point Surveys
	B2) BMP specifications result in temporary stream crossings are adequately designed and stabilized, and removal and restoration of crossing is adequate, such that accelerated streambank erosion will not occur and sediment delivery to streams will not degrade aquatic habitats or negatively affect other water uses.	-Channel Condition Surveys -Photo Point Surveys -Stream Features Surveys -Channel Substrate Transects
C) Construction Techniques WAC 222-24-030 (2) & (4)-(9)	C1) Road cuts are subject to surface erosion, ravel, and mass wasting, which may result in sediment delivery to streams.	-Erosion Pin/Bridge Networks -Photo Point Surveys -Erosion Mapping/Sediment Routing -Sequential Aerial Photography

C) Construction Techniques (cont.)	C2) Sidecast or roadfill material is subject to erosion, or overloading of slopes from sidecast or fill material may cause mass wasting, and sediment from these sources may enter the stream system in amounts that degrade aquatic habitats or negatively affect other water uses.	-Erosion Pin/Bridge Networks -Photo Point Surveys -Erosion Mapping/Sediment Routing -Sequential Aerial Photography -Channel Condition Surveys -Channel Substrate Transects -Sidecast Overburden Surveys
	C3) BMP specifications for stabilization of cuts and fill slopes and requirements that sidecast material not be left within the 50-year floodplain of Type 1-4 waters or on slopes that the DNR has determined are potentially unstable are adequate to ensure that sediment delivery to streams will not degrade aquatic habitats or negatively affect other water uses.	Same as for Hypotheses C1 & C2
Road Maintenance		
D) Active Haul Roads WAC 222-24-050 (2) & (4)	D1) Road surfaces are subject to erosion, and road drainage facilities may cause mass wasting if not adequately maintained, and sediment from these processes may be delivered to streams in amounts that degrade aquatic habitats or negatively affect other water uses. D2) BMP specifications for maintenance of active roads are adequate to result in road surfaces that are maintained to minimize erosion of the road surface/subgrade and culverts and ditches that are kept functional, such that erosion of road surfaces or mass wasting caused by inadequately maintained drainage facilities will not result in sediment delivery to streams in amounts that degrade aquatic habitats or negatively affect other water uses.	For D1 & D2: -Road Surface Condition Survey -Culvert Condition Survey -Runoff Sampling -Road Drainage Mapping -Photo Point Survey -Channel Substrate Transects -Pool Infilling -Macroinvertebrate Surveys
Harvesting		
E) Tractor & Wheeled Skidding WAC 222-30-070 (1)-(5) & (7)-(9)	E1) Skidding practices may disturb soils in a way that facilitates erosion and sediment delivery to streams, and skidding in and around small streams may destabilize stream channels and accelerate stream bank erosion. E2) BMP specifications for tractor and wheeled skidding are adequate to avoid excessive erosion and protect streams, such that erosion and subsequent sediment delivery to the stream system and destabilization of stream banks and channels will not degrade aquatic habitats or negatively affect other water uses.	For E1 & E2: -Photo Point surveys -Channel Condition Surveys -Stream Features Surveys -Channel Substrate Transects -Erosion Pin/Bridge Networks -Pool Infilling -Sequential Aerial Photography -Macroinvertebrate Surveys -Amphibian Surveys
F) RMZs & RLTAs WAC 222-30-020 (3)-(5)	F1) BMP specifications for Riparian Management Zones (RMZs) and Type 4 Water Riparian Leave Tree Areas (RLTAs) are adequate to prevent disturbance of stream banks and channels and prevent excessive sediment delivery to streams, such that stream disturbance and sediment delivery will not degrade aquatic habitats or negatively affect other water uses.	-Photo Point surveys -Channel Condition Surveys -Stream Features Surveys -Erosion Pin/Bridge Networks -Macroinvertebrate Surveys -Amphibian Surveys