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Development of a Repeatable Regional Protocol for Performance-Based Monitoring of Forestry Best Management Practices

Roger Ryder
Pamela J. Edwards

Abstract

There has been a long-standing interest in improving Best Management Practice (BMP) monitoring within and among states. States monitoring the implementation and effectiveness of BMPs for forest operations take a variety of approaches. This creates inconsistencies in data collection and how results are reported. Since 1990 attempts have been made to develop a consistent BMP reporting methodology; the attempts have met with varying degrees of success, utility, and acceptance. Traditional monitoring focused on individual BMPs in terms of prescriptive guidelines, but this approach created inconsistent monitoring methodologies. To improve consistency and allow a more universal method for BMP monitoring, the approach to developing the protocol, described herein, focuses on the underlying "principles" which guide the design and applicability of BMPs. Shifting emphasis to the underlying principles facilitates outcome or performance-based monitoring of BMPs, which is a more universal, less subjective, and more direct means of evaluating BMP performance for protecting water quality. In turn, repeatability is improved. In this paper we discuss the development process and initial testing of a consistent repeatable BMP monitoring protocol for timber harvesting activities adjacent to water bodies. The protocol could be applied across much of the United States.

The Authors

ROGER RYDER was the northern team leader for the Policy, Planning and Management Division of the Maine Forest Service. He earned his B.S. in forestry from the University of Massachusetts and M.S. degree in forestry from the University of Maine. He was the principal developer of the early drafts of the Regional BMP Protocol and led its development from inception in 1999 through 2003.

PAMELA J. EDWARDS is a research hydrologist with the Northeastern Research Station's Timber and Watershed Laboratory in Parsons, WV. She earned B.S. and M.S. degrees in forest science and forest hydrology, respectively, from The Pennsylvania State University, and a Ph.D. in forest soils from North Carolina State University. She has conducted watershed management and forest hydrology research since 1981.

Cover Photos, clockwise from left: stream and riparian area, road and stream crossing, and log truck and forwarder at a landing; first two photos by Roger Ryder, third photo by Albert Todd.

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Introduction

In the United States, the U.S. Environmental Protection Agency (U.S. EPA) regulates water pollution through various permit processes. Non-point source pollution specifically became addressed in sections 404, 208 and 319 of the 1972 Clean Water Act (CWA) and its reauthorization in 1993. These sections exempt silvicultural and other forest operations from needing permits through Best Management Practice use and reporting. As a result, states developed unique sets of forestry BMP guides or rules to protect water quality; each state must prove to U.S. EPA that BMPs are being implemented (Ryder et al. 2003).

To meet implementation and reporting requirements, states take various approaches to monitor BMP implementation and effectiveness (Edwards and Stuart 2002). Although U.S. EPA has supported development and publication of general guidelines, such as Dissmeyer (1994), there are no standards or required procedures set by federal law for monitoring and reporting requirements. Consequently, there is inconsistency among states in effectiveness and the rigor used to evaluate BMPs. These inconsistencies are among several factors that have allowed and contributed to criticisms by individuals inside and outside the forestry profession regarding whether BMPs are as effective as they are purported and whether forestry should continue to receive a silvicultural exemption.

In response to concerns from U.S. EPA and other federal agencies regarding inconsistent environmental monitoring for all industries, a national Water Quality Monitoring Council was established in 1997 to develop a basis for rational monitoring, comparative methodologies, and consistent analysis and reporting. More recently, the National Council of Air and Stream Improvement (NCASI 2001) reinforced the need for better quality data to evaluate forestry BMPs when they stated: "Most states recognize the potential for water quality impairment from timber harvesting, especially soil erosion and sedimentation caused by roads and stream crossings. The states repeatedly report a serious lack of monitoring information, and generally fall back on widely accepted generalizations about the impact of timber harvesting on water quality." However, many of these widely accepted generalizations are not well founded in terms of rigorous analysis. Many originate from studies that measured surrogates of BMP effectiveness rather than direct BMP effectiveness, or they were limited in terms of spatial replication (both locally and regionally) and long-term evaluation of effectiveness (Edwards 2004).

To credibly evaluate the effectiveness of forestry BMPs, it has become necessary to take a more scientifically rigorous, consistent, and supported approach. Development of a consistent, repeatable protocol with wide application is one way to achieve credible evaluations. The objectives of this project were to identify the key components of a wide-area protocol and determine if a regional or wide-area repeatable BMP monitoring protocol could be developed (and tested) utilizing the underlying principles of BMP practices, while still maintaining state control over BMP guidelines.

A Regional BMP Monitoring Protocol for timber harvesting as it relates to water quality, funded by the USDA Forest Service and U.S. EPA, has been developed and tested in 11 states in the northeastern United States. Recommendations by Beard et al. (1999) were used in the overarching framework of protocol development using consistent data-gathering with well documented procedures to ensure results are reliable and comparable to other data collected with the protocol and to other studies. In this paper we describe the steps taken thus far in protocol development, some features of the protocol, and important components that were found to be key elements for protocol development. The on-site evaluation using the protocol should compliment and benefit other water quality evaluations, such as water chemistry and biologic assessments.

An extensive test of the protocol began in five northeastern states in June 2004. A final report on the test results is expected in early 2006. Collaboration continues with local, state, federal, and research interests from various sections of the country to: (1) ensure the protocol can be used in diverse field situations; (2) ensure scientific credibility; and (3) identify BMP guidelines that address specific local or regional concerns and needs but cannot be evaluated well with the current protocol questions. This information will be used to revise the protocol to improve its performance and expand its applicability.

Process of Protocol Development

The initiative to develop a protocol originated from the Sustainable Forestry Initiative (SFI) BMP training sessions for loggers and foresters in Maine and from the Maine Forest Service's intent to modify and improve the state's BMP implementation and monitoring program. On-site interactive BMP field training for loggers, road construction and maintenance crews, and foresters demonstrated the need for and had the greatest influence on subsequent protocol development. Questions and open discussion that arose during training led to a change in the approach to questions for on-site BMP evaluation. Questions similar to: "How do we know we installed a water bar correctly?" or "What is the water bar suppose to accomplish?" created an investigative approach that focused on outcomes or performance. The shift from "What does the BMP manual require?" to "What is the expected outcome or performance?" led to a landslide of creative thoughts. As this change in thought process occurred, training approaches also shifted toward meeting outcomes or performances instead of prescriptive measures. This allowed exchange of ideas and removed barriers that previously had impeded technology transfer. In a 3-year period, more than 200 loggers, foresters, and road construction personnel participated in the interactive training in Maine. Due to the changes in the training approach, instructors were asked to document questions and associated answers from the workshops and create a performance-based training and evaluation guide for BMPs. These questions evolved into the first draft of the BMP evaluation protocol.

To move the protocol along more formally, Maine's Forest Advisory Team (FORAT), which consists of a diverse group of stakeholders with various interests and knowledge of BMPs, provided and solicited input and guidance. The team focused on reducing the subjectivity of data collection and improving the understanding of terminology. Information from the SFI BMP training sessions was used to focus and enhance discussions. One specific field site evaluation by FORAT members provided the single most influential event illustrating the need to focus on BMP principles and outcomes. The team initially scored a harvest site as failing because no BMPs were observed during an inspection, but upon further investigation the participants found no evidence of sediment delivery to the stream or other soil movement/deposition concerns. This situation created the opportunity to focus on the difference between following a BMP manual (i.e., a prescription) versus meeting specified performance objectives. Using performance objectives, the team re-evaluated the site and rated it as excellent in controlling sediment and soil movement. Ultimately, they acknowledged the activities on the site had been well planned, which is a very important BMP practice. Without focusing on performance, it is difficult to give credit for good planning. As a result of this field test, efforts to improve the monitoring protocol began focusing on performance and outcomes.

As the protocol became more formally developed into a usable document, the USDA Forest Service's (USFS) Northeastern Watershed Team and U.S. EPA became interested and offered funding to expand the protocol development within the 20 states in the USFS Northeastern Area and Virginia (Fig. 1). The importance of involvement by U.S. EPA's Washington Office staff

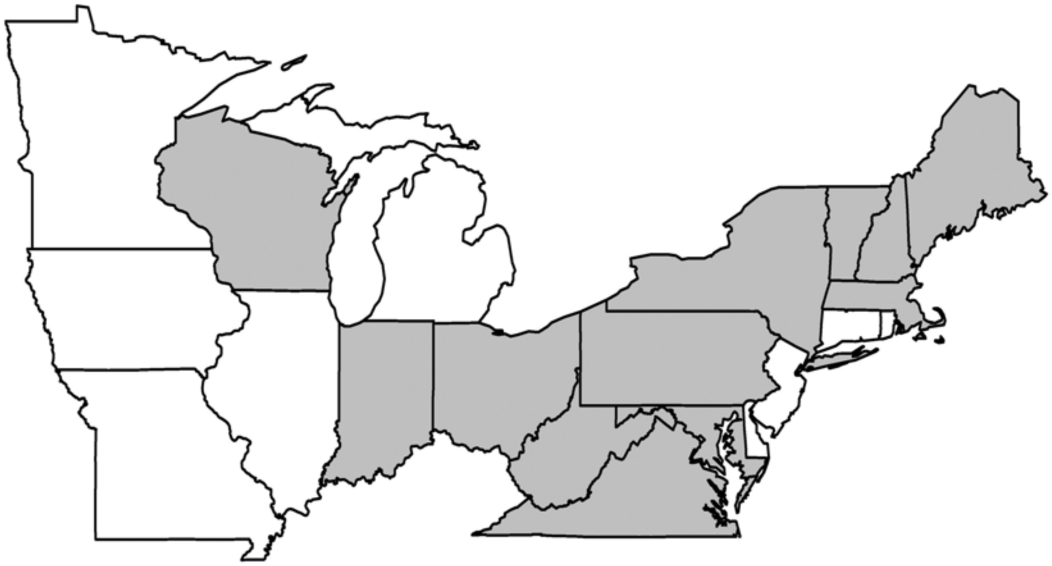

Figure 1.—Data collection for and testing of the various versions of the Regional BMP Protocol occurred in states that are shaded on this map.

during the early stages of development was essential to ensure consistency between this project and U.S. EPA's National Management Measures (U.S. EPA 1993) for forestry non-point source pollution. The National Management Measures are a guide and a resource for states when developing their BMPs.

States, watershed projects, a variety of organizations, and individuals were invited to participate in the various steps of the protocol development, testing, and review (Appendix). Participants included representatives from Maryland, West Virginia, Virginia, Pennsylvania, Ohio, Indiana, Wisconsin, Vermont, Massachusetts, New Hampshire and Maine, the New York City Watershed Council, Maine's Atlantic Salmon Commission, the Chesapeake Bay Project, EPA Washington Office staff, American Forest and Paper Association, Master Logger Program of Maine, Master Logger Program of Maryland, Northeast Area State Foresters Association, MeadWestvaco, International Paper Company, a variety of independent foresters, and other stakeholders. After receiving training on the protocol's use, representatives throughout the northeastern area and Virginia (Table 1) tested the protocol to ensure the protocol's performance-based approach and methodology were valid across this wide area. Regional testing matured the protocol from a state protocol to a regional protocol.

Protocol Contents

The Regional BMP Monitoring Protocol is a living document and has undergone multiple iterations, and continues to be refined. The protocol is an expert system that is the culmination of multiple experts' input, for which a repeatable process is used to identify problems and solutions. Expert systems transfer expert knowledge, experience, and process into a format that other nonexperts can follow; the results of an evaluation are the same or very similar to those that would have been obtained by experts in that field of study.

A series of questions with associated answer options was developed to create a data collection form. The question sequence is structured as a dichotomous key, like those used for tree identification. The answer for a question determines the subsequent sequence of questions. The end result is similar to a trouble-shooting guide for problem solving. This approach to evaluation and technology transfer is well documented in the medical profession and is employed to develop a consistent and effective triage process in hospital emergency rooms (Brieman et al. 1984). Such a systematic approach increases the probability that each site evaluation (or any evaluation process) will be conducted in a methodical and unbiased manner.

Table 1.—List of participants that conducted field tests and/or collected data.

State or organization that field tested and/or collected data	Field test participant 2002	Sample data collection participant 2002	Field test participant 2003	Sample data collection participant 2003
Maryland DNR, Forest Service	X	X	X	X
New York City Watershed Council	X	X		
Indiana DNR, Div. of Forestry	X	X	X	X
Ohio, DNR, Forestry	X		X	
West Virginia, Div. of Forestry	X		X	
New Hampshire, DRED	X		X	X
Wisconsin, DNR	X	X	X	
Pennsylvania, DCNR, Forestry	X	X	X	
Vermont, DNR			X	X
Massachusetts, DNR	X		X	X
Maine, DOC, MFS	X	X	X	X
MeadWestvaco, Maine	X	X		

Because the protocol focuses on performance, the areas evaluated for BMP effectiveness at each forest operations site, or sample unit (Fig. 2), are those most likely to be involved with contributing sediment or acting as a conduit for sediment delivery to water bodies, influencing shading of water bodies, and altering the hydraulics of water due to the crossing structures. Consequently, the focus is on areas in close proximity to water bodies (the area immediately outside the riparian buffer, the riparian buffer, and the water body crossing) and the water bodies themselves; these areas comprise the sampling area (see sidebar, "Sampling Units"). The protocol evaluates different components of the sampling area, such as the road approaching the water crossing, the water crossing, and the riparian area. Evaluation in the sampling area starts at the furthest point from the water body and proceeds toward the water body. For example, the evaluation of a haul road water body crossing starts outside the riparian buffer, at a distance defined by slope distance outside the buffer. Next the area inside the riparian buffer is evaluated, followed by the water body crossing. The haul road approach for the opposite side of the water body then is evaluated in the same manner. This process ensures all areas are evaluated, protocol questions are answered, initial visual perceptions do not alter or short-circuit the evaluation process, and subsequent statistical analysis compares variables collected from like situations.

The protocol is composed of multiple sections: (1) general information, which includes socially focused questions, such as landowner types, harvest unit acreage, and involvement with state stewardship programs, logger training, and certification programs; (2) water body crossings (haul roads and skidder crossings) and associated approaches; (3) haul roads located within a riparian or buffer area; (4) hazardous material handling and disposal; and (5) riparian or buffer areas. Where relevant, each section (e.g., a water body crossing) has a subsection with questions about site attributes, such as slope of land and specific soil information.

Sampling Units

The Regional BMP Monitoring Protocol defines a sample unit as "a contiguous harvest unit that includes either or both a riparian zone or a water body crossing. It is bounded by any combination of water bodies, the boundary of the harvest area, or a land ownership boundary. The sample unit starts when a water body is crossed or a riparian area entered [assumes entrance by a road or trail]. A new sample unit begins each time a water body is crossed and ends at the next water body, the edge of the harvest area, or the land ownership boundary, whichever is encountered first." The outer boundary of the sampling area is defined (in feet) by the length of the slope distance outside the riparian buffer where there is greater than a 5 percent change in slope for a minimum distance of 25 ft.

To envision this concept, it may be helpful to think of the harvest area as a house and the sample units as rooms in the house. The house has several rooms; when you pass through a doorway you move from one room into another. Similarly, in the sample unit framework, the doorway represents a water crossing, and each wall represents a property line, riparian zone, or edge of a harvest. As you cross a water body, you enter the next sample unit.

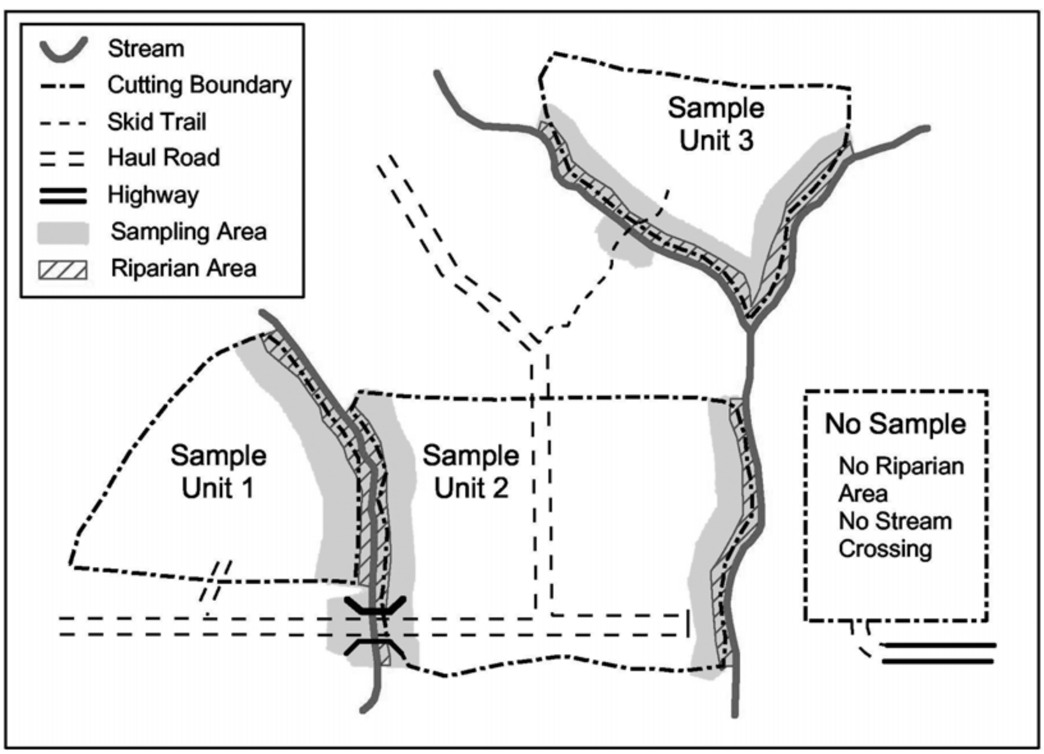

Figure 2.—Examples of sample unit boundaries in the Regional BMP Monitoring Protocol.[1] The shaded area is a combination of riparian buffer width plus a defined slope distance outside the riparian buffer. Sample Unit 1 has only a riparian buffer and the boundaries of the harvest to delineate the sample unit and no water crossing; Sample Unit 2 has a water crossing and two riparian buffers and the boundaries of the current harvest to delineate the sample unit; Sample Unit 3 has a water crossing, a riparian buffer and the boundaries of the current harvest to delineate the sample unit. Note: when a water body crossing is part of a sample unit, the entire water crossing and the associated approaches are considered part of and evaluated as a component of the water crossing, though the approaches may be in another sample unit.

[1]Ryder, R.; Post, T.; Welsch, D.; Sykes, K. 2003. **Regional BMP monitoring project grant report.** Unpublished report. On file at USDA Forest Service Northeastern Area State and Private Forestry, Durham, NH.

During development of the protocol, a concern was raised: Are new issues, such as fish passage and large woody debris, evaluated sufficiently? To some degree, this illustrates the evolution of interpretation of the Clean Water Act. Consequently, we solicited expert advice and altered and added questions, which were guided by recent research.

The protocol has three intents: (1) monitoring BMP performance related to water quality; (2) obtaining information to assist trainers in focusing future education to areas needing improvement; and (3) highlighting trends in water quality protection. This plurality of protocol objectives is accomplished using cause and effect questions imbedded in the series of questions related to BMP implementation. A series of questions related to a haul road crossing might ask about the type of road construction, duration of road use, if and how far soil moved, type of soil that moved, cause of soil movement, and quality of BMP practice implementation. These questions allow preliminary analysis of BMP performance and assist in identifying areas to emphasize in future training.

Balancing the temptation to add questions against the desire to eliminate questions for brevity required patience and creativity. Each question was evaluated for its importance in answering a larger, more holistic question. For example, to evaluate the larger question: "Does the water body crossing structure allow fish passage?", individual questions about the crossing structure that are known to inhibit or encourage fish passage were asked. These included questions about the presence or absence of continuous natural substrate through the bottom of the crossing, whether a hanging or perched culvert was present, or if the crossing structure was narrower than the active channel width. Each of these questions can be answered more objectively and precisely than the larger, potentially more subjective question, and each answer provides information needed to determine whether fish passage is possible. If a question does not provide important information or if it provides redundant information obtained from other questions, it is eliminated. Typically, several iterations are required to evaluate the value of each of the questions in the context of the current body of questions.

The protocol process may overwhelm a new user. However, with a 1½ day training session and experience of evaluating approximately 10 sample units, one person typically can evaluate a haul road water body crossing in about 20 to 30 minutes[1]. Maintaining a reasonable evaluation time per sample unit is paramount to controlling the costs involved with protocol use or any other monitoring process. The dichotomous key structure, which requires that only relevant questions be answered (e.g., see Appendix), and limiting the questions only to those most essential to answering the larger question, controls costs and user time.

Factors Considered During Protocol Development

Terminology, Definitions, and Phrasing

The first, and perhaps most important step is to ensure the potential for broad use and consistent evaluation was to establish single definitions. Definitions have to be applicable across the entire area of consideration, and all users need to be willing to accept and use them during protocol application, data analysis, interpretation, and dissemination of results. Common terminology and definitions assure that questions about BMP implementation and performance are interpreted and answered consistently across responders. Access to definitions in a glossary provided at the end of the protocol helps to assure that all subsequent summaries or analyses concerning BMP performance are not suspect or open to multiple interpretations.

It is paramount to develop and accept common terminology and definitions. People have strong bonds with the words they use, and words may carry cultural, professional, educational, political, or socio-economic associations. As a result, people have limits of comfort with the definitions of words they use. Consequently, no single person controlled the wording or definitional development of the protocol, and concession and consensus were important. Acceptance was essential from the many diverse parties that are expected to use the protocol and the individuals that will employ the resulting information.

During the various testing stages of protocol development (Appendix), we sought written comments and suggestions for improvements pertinent to wording and terminology. To date, approximately 250 individuals have seen and reviewed at least a portion of the protocol, and approximately 75 individuals have field tested the protocol in 11 states. The current protocol has undergone seven major verbiage edits. These changes clarified terminology, specific wording of the protocol questions, on-site application of the protocol, and answer choices. To improve the understanding and comfort level with definitions and terminology, we sometimes employed the use of local qualifiers in addition to definitions. Along with local qualifiers, we continually improved or expanded definitions using descriptors that might be more widely known and understood. For example, when evaluating the adequacy of (stream crossing) culvert widths, local qualifiers and scientific descriptors were provided to consistently evaluate culvert widths with respect to the active channel width. Since stream channel width usually is defined scientifically as the width at bankfull stage, that definition is included. But we also included the term "width at the normal high water mark" because this is a term commonly used in many localities to describe essentially the same feature.

Another example of word preferences is illustrated by the following example. In the protocol, a question originally asked "How far was sediment delivered into the riparian buffer?" This wording was changed to "How far was sediment moved into and through the riparian buffer?", because the word "delivered" held a more regulatory context for some people than the word "moved".

The term "ephemeral stream" was very contentious and resulted in a substantial amount of debate among users. Many states have less stringent riparian/buffer and BMP requirements for ephemeral streams; these requirements affect the economics of the forestry operation. Thus, people did not just define ephemeral streams differently, but there often were costs consciously or subconsciously associated with the term that affected how easily a person was willing to consider a different definition.

Identification and Focus on Underlying Principles of BMPs

There are literally hundreds, if not thousands, of forestry BMP practices that exist across the United States. Some are regionally specific, such as methods to perform forest operations in wetlands. Others may be more broadly applicable, such as road placement considerations. Examining individual BMPs is a prudent approach to evaluate implementation locally, but a protocol that evaluates individual BMPs within a regional or wide-area program would be so large and cumbersome that it would never be accepted. However, forestry BMPs are based on underlying principles of physics and chemistry (Edwards 2004), which are relatively small in number and well understood. Consequently, if the principles behind BMPs are identified, it is possible to develop a manageable wide-scale protocol that focuses on principles that group BMPs by category rather than each specific BMP.

For example, soil stabilization has a well founded basis in science. BMP guides typically recommend exposed mineral soil be sloped with various run-to-rise ratios, such as 2:1 or 3:1. The scientific principle is the angle of internal friction of the soil, which relates to the angle of repose of the soil (Holtz and Kovacs 1981). Since there are a multitude of soils with ranges of angles of repose in a state or region, averages or the most common angles of repose are used in BMP guides. In addition, covering exposed soil to minimize initiation of soil movement by rain impact, improving infiltration, and establishing vegetative root growth are well founded principles in soil physics (Schwab et al. 1993). Hence, protecting exposed mineral soil slopes with mulch and vegetation and creating slopes less than the soil's natural angle of repose are examples of BMPs developed from underlying principles of soil stabilization.

Water bars, diversion ditches, wing ditches, broad based dips, and out-sloped roads are a few of the many available individual BMP practices used to control erosion on roads. Each has the common underlying principle of controlling the energy of the water on the road surface by moving water off in small parcels, rather than allowing it to concentrate and build energy (Packer 1967). As such, the performance of water flow control practices can be evaluated visually by examining for the presence of physical evidence of sheet erosion, rills, gullies, mass wasting, ruts, etc., and quantitatively using measurements of the depth, length, and size of scoured or deposit areas and their terminus.

Obviously this type of approach assumes observable or easily measurable evidence that the practices were successful in meeting the underlying principles of the practice or combined practices. This may not always be true, particularly for small problems, such as one-time minor additions of sediment or locations of only minor erosion. But the more chronic problems that are of primary concern usually have some visually obvious symptoms that can be used to determine where BMPs were not used, were used inappropriately, or were inadequate, and assist with determining the degree of performance.

The "principle" concept can be applied to any BMP that has a scientific foundation based on one or more principles. However, it is possible that no underlying scientific principle for a given BMP exists, and instead it is based on social or political considerations, such as desiring to know if a forester was involved in the harvest or if BMPs were specifically required in a contract. In such cases, the underlying social or political principle must be identified so field measurements or information collected can be designed to focus on metrics of this principle, and data can be collected, analyzed, and reported in the same consistent manner as for scientifically principled BMPs.

The fundamental shift to an approach focused on principles alters how BMP implementation training is conducted and shifts the focus to performance of BMP application rather than the prescriptive measures themselves. Prescriptive measures offer a guide to implementation, but these guidelines do not determine or necessarily improve performance. In the principle approach, BMPs are planned, designed, and implemented based on whether the BMP is needed at that location and its potential for success in controlling a performance measure (e.g., Will it keep sediment from reaching the stream?). Thus, thought processes will shift from solely using prescribed guidelines, such as cross-drain culvert spacing distances based on grade, toward including consideration of performance to control sediment production along the road length based on field conditions, experience, etc. This approach will not eliminate all problems because not all problems and potential BMP mitigations can be anticipated before or even during an operation. Nor does it preclude states from maintaining control over guidelines or specific BMPs. But the approach does promote greater consideration of the local conditions and potential problems and solutions up front, rather than simply following prescriptions with little thought of how appropriate or effective that BMP may be. Performance-based decisions may result in cost reductions because BMPs can be applied where and when they are most needed and they allow improved planning and evaluation of planning. Furthermore, as regional and national data are analyzed, the results may identify universally or regionally problematic situations or situations where problems are rare, which also may result in making BMPs more environmentally and cost effective.

Reducing Subjectivity and Increasing Repeatability of Data Collection

For any protocol or similar tool to be useful, it is necessary to design it so the metrics are largely or fully quantifiable. This approach reduces subjectivity and results in identical or similar answers to each protocol question regardless of who collects the data. This characteristic is necessary to make the protocol and its findings relevant and credible.

The Regional BMP Protocol is intended to be similar to the USFS Forest Inventory Assessment program which collects data in a consistent repeatable format from the various forest types across the United States. Consequently, subjective words were avoided in the Regional BMP Protocol questions, as different individuals interpret or apply them differently. For example, terms such as "excessive", "minimum", "acceptable", "low impact", and "short-term" will be interpreted and used differently among individuals and states reporting BMP performance. To avoid different interpretations and subjectivity, questions are worded specifically and clearly. A question such as "Is the BMP practice effective?", will result in a subjective answer, whereas the question "Is a rill evident?" is much less subjective, particularly when the definition of a rill is provided. In this case, the definition of a rill is based on quantifiable measurements of width, length, and/or depth and provided in the glossary. Similarly, a question such as "Is sedimentation on the stream bank and/or in the stream substantial?" could be reworded "Are sediment accumulations on the stream bank and/or in the stream greater than or equal to [one of the defined answer choice categories or measurements]?"

Dependable evaluation of BMP effectiveness also depends on when the sample unit is evaluated. Presuming that conditions generally improve over time, as many studies suggest with either direct or indirect measurements of BMP effectiveness (Hornbeck and Kochenderfer 1999, Kochenderfer et al. 1997, Lynch and Corbett 1990), it is best to evaluate BMPs when their effectiveness is most tested – during or soon after forest operations when soil disturbance is typically greatest. Waiting longer may conceal some effects and suggest better BMP effectiveness than actually occurred, due to either natural or later human rehabilitation on the site. Alternatively, infrequent extreme rain events could create much greater change to the site than was caused by the operation. New disturbances also could occur that were not linked to the forest operation, such as off-road vehicle use, if too much time exists between the forest operation and effectiveness monitoring, and the more contemporary disturbance could be attributed erroneously to the operation. The Regional Protocol requires monitoring be completed within 1 year from the time site activities are completed, though monitoring during or immediately after the operation is recommended.

Protocol precision is reassured by having duplicate evaluations of the same sample unit done by different people or teams. One type of repeated measurements on a subset of sample units can be made by a quality assurance/quality control (QA/QC) team member at the same time data are collected by the primary individual assigned to data collection. These are referred to as "hot checks" and are critical to improve future data collection. Hot checks also are valuable as educational tools for data collection crews[1]. In addition to hot checks, repeated evaluations can be done by different people revisiting subsets of sample units sometime after the first evaluation. It is essential that the repeated evaluation be completed soon after the original review so answers to questions are not affected by the time lag. For example, different answers to the question "Is a rill evident?" might be expected if a road is evaluated immediately after road construction before rain events occurred compared to 6 months later at the end of the rainy season. To ensure improvement in protocol precision, the individual conducting the repeat sampling should follow a set process to reconcile the reason(s) for dissimilar answers. Repeated evaluations during visits have been used more commonly than hot checks to verify precision of the Regional Protocol, but both are important techniques for identifying unclear questions or those that may regularly provide imprecise answers.

Repeatability should be assessed during development and after the protocol is accepted to ensure continued repeatability and potential areas for question refinement. The degree of repeatability should be determined and reported annually or on some regular, convenient basis as part of the quality assurance portion of the protocol. The required number of repeated measurements can be determined by the costs of repeating measurements or on tests of statistical power. The latter is more statistically sound and provides quantifiable levels of confidence in the results. But if the number of statistically defined repeated measurements is too expensive or time consuming, basing repeated samples on economics is a better alternative than not performing repeated measurements, though the information may not be as accurate as a statistically valid sample.

In the first phase of the Regional BMP monitoring project, 30 percent of the sample units were revisited for replication testing. This equals 620 questions replicated, which was 17 percent of the total number of questions answered for all sample units. The percentage of questions replicated does not equal the percent of sample units resampled because each sample unit may not include attributes from all the sections of the protocol; for example, not all sample units have a water body crossing. Therefore, each sample unit may have a different number of questions based on the components of the sample unit, and each sequence of questions within each section of the sample unit may vary due to the dichotomous structure of the protocol questions and answers. No sites evaluated in the first phase of testing had haul roads in the riparian buffer, so no questions ever were answered in this section. All other sections were evaluated by a second team. The first phase results indicated 71 percent of the 620 replicated questions had identical answers from the two evaluators/teams who visited the same site independently. The two independent site evaluations occurred in the same field season and typically within a 2-week period. Since this is the first testing of the replication process, the level of replication that will be possible or considered acceptable currently is unknown. However, the current goal of the project is to obtain an overall replication rate of 90 percent, which is comparable to the Forest Inventory and Assessment program goals for similar types of data collection. The continuous improvement process in the next phase of testing adds a reconciliation component to gain insight for improving replication of site evaluations and specific questions.

Repeatability also is a function of space. In the Regional Protocol, the general location of the forestry operation is defined as a sample unit. As mentioned earlier, because the protocol focuses on BMPs and their role in protecting water quality, sample unit boundaries are defined in terms of their proximity to water bodies. Where multiple sample units exist in a single forest operation, one, some, or all of the units can be selected for evaluation, depending on the design of the sampling scheme. Geographic Positioning System (GPS) coordinates are determined on site during protocol use to identify the location of the sample unit either at the entrance to or at the primary log landing in the sample unit. This assures quality assurance checks and site re-evaluations are done within the correct sample units.

After initial evaluation of the sample unit, a resampling strategy should be developed to evaluate the long-term performance of BMPs. Ideally, long-term subsampling should be done annually, though many states probably will not have the resources to resample that frequently. Sample units chosen for resampling do not have to be selected randomly; they can be stratified and selected in a way that provides the state with the information with which it is most interested concerning long-term BMP effectiveness. For example, sample units can be categorized based on results from the initial evaluation or by site factors, such as soil erodibility potentials, terrain conditions, harvesting systems, etc. From this information, units can be selected for resampling based on their potential risk, probable concern, or initial effectiveness.

Consistent and Transparent Data Analysis and Reporting

Ultimately, the reasons for having a protocol to evaluate BMP performance are to analyze the data, distribute results, provide meaningful measures of BMP performance, identify common weaknesses of BMP implementation, develop or revise BMPs and BMP recommendations and guidelines, and potentially target BMPs to specific conditions where they are most needed and provide the most utility. All of these actions require credible results. Thus, consistency is as important for data analysis and results reporting, as it is for measuring performance in the field.

Analytical consistency does not mean that each year's tests are limited to the same ones used when only 1 year of data were available. Instead, consistency means that data must be analyzed using accepted mathematical and statistical procedures. Analyses must never be structured to prove a priori conclusions about the data. However, analyzing data in various permutations or groupings is encouraged to extract from the data as much useful information as possible. As multiple years of data become available, additional analyses may be possible or useful due to increases in the number of samples, temporal trends in the data, or if additional testable inferences were insinuated but not conclusive from prior years' data.

Data analysis should be transparent; that is, the analytical and mathematical procedures used should be explained clearly. Also, one should explain the way data were identified as suspect (i.e., statistical outliers, suspected problems with data loggers, data entry mistakes, etc.) and how those data were handled during analyses (e.g., removed from the data set, included in only some analyses, etc.). Reasons for excluding any data point always should be disclosed, but data should be excluded only rarely and for well defined reasons. If suspect data become increasingly common, the reason for them should be identified and rectified. Solutions may include improved wording in the protocol, better field training for users, or repairing faulty data-collection equipment. Currently, oversight to maintain consistency is monitored by the USFS Northeastern Area State and Private Forestry in Durham, NH.

Providing a consistent reporting format among states and regions is an essential component of the protocol to illustrate how BMP performance is quantified, demonstrate trends in performance over time, and identify areas of BMP weakness. Transparent analysis, documentation, and dissemination of results also will provide consistent, scientifically based information pertinent to forestry's CWA silvicultural exemption and will be useful in allaying public suspicions about forestry's resistance to revealing environmental effects. Within the forestry profession, consistent reporting has the potential to create many educational and training opportunities.

Information About the Protocol

More information on the protocol and how to implement it can be obtained by contacting the authors or a USFS Northeastern Area Watershed Team member. The authors can be contacted at the following e-mail addresses: ryderbmp@yahoo.com or pjedwards@fs.fed.us. The Northeastern Watershed Area Team leader for this protocol currently is David Welsch, who can be contacted at dwelsch@fs.fed.us.

Currently, a set of computer programming queries is being developed which will provide states or individual users with results summary. Additional user-defined analyses also may be performed on the data to extract other needed information. These queries are expected to be completed by spring 2006. When completed, both the queries and the Regional Protocol will be published by the USDA Forest Service.

Conclusion

To improve consistency and repeatability, and to allow a more universal approach for monitoring BMP performance, this protocol focuses on the underlying principles of BMPs. This approach is in contrast to evaluating BMP compliance based on prescriptive guidelines, such as cross-drain spacing on roads, or monitoring each specific BMP, which is impossible over a wide region that employs hundreds or thousands of BMPs, or monitoring surrogates of BMP effectiveness, such as turbidity levels downstream from a forestry activity.

The current form of the protocol was developed after input and critique by hundreds of individuals and by on-site field-testing in 11 northeastern states. Initial testing demonstrated wide-area or regional BMP monitoring is capable of producing repeatable results across diverse harvest situations while still allowing states to retain control of their BMP guidelines. The protocol has been revised several times and has undergone additional broad-scale testing during the 2004 field season.

Key elements used in developing the wide-area BMP monitoring protocol, which is an expert system, were (1) an extensive collaboration process with a wide variety of stakeholders; (2) consistent terminology; (3) use of BMP principles rather than prescriptive practices; (4) quantitative reproducible results; (5) transparency of analyses and results; (6) credible quality control and quality assurance procedures; and (7) regular revision to improve and make it more widely applicable. Improving credibility of forestry BMP monitoring is dependent upon a peer reviewed, repeatable, objective evaluation process that is considered acceptable to diverse stakeholders. This protocol could be valuable for site evaluations in conjunction with water chemistry monitoring and biologic assessments; combining multiple monitoring systems may lead to a better understanding of BMP performance and effectiveness in protecting water quality from forest operations.

This protocol focuses on BMP monitoring for timber harvesting. Similar monitoring protocols could be developed from this same process for other forestry activities, such as site preparation. Other nonforestry uses, such as recreation trails and public roads that cross water bodies, also may find utility in this approach.

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Appendix

Steps used in the development, testing, and review process for this Regional BMP Protocol.

1. Identified questions that would elicit an outcome-based answer to evaluate quality of BMP implementation.
2. Identified an appropriate set of answer choices that are easily identifiable. (Answers reflect ranges of on-site conditions to reduce subjectivity.)
3. Edited questions and answer choices to minimize subjectivity.
4. Identified questions that assisted with relating activities and outcomes.
5. Ensured questions and answer choices had a scientific underlying principle (see Identification and Focus on Underlying Principles of BMPs section, page 7); grouped practices by common underlying principles. This process required substantial literature review and discussions.
6. Developed a consistent on-site evaluation procedure.
7. Formulated questions and arranged answers into a dichotomous key to determine the next series of questions to be answered.
8. Field-tested questions, associated answer choices, and evaluation process. Initial trials and testing were conducted using a written protocol.
9. Programmed protocol questions and answer choices into a data dictionary for use in Global Positioning System units. This eliminated redundant data entry and improved data analysis since all answers are in a consistent format.
10. Modified and edited questions, answer choices, and the evaluation procedure to improve the protocol based on comments after field testing. Only comments that were scientifically justified and relevant were incorporated. Keeping protocol questions focused on the topic required patience, diplomacy, and an acceptance to new ideas and perceptions. This step was repeated seven times (in two major regional trials).
11. Analyzed questions for repeatability and made appropriate corrections after the first regional test. Conducted a 2-day meeting to discuss how collected data would be presented and summarized in annual reports, identified concerns and areas needing improvements that must be addressed to continue developing the protocol further. This meeting included project participants and newly interested parties.
12. Transferred protocol questions to Palm Pilots™ for the second regional trial, thereby allowing the user to “skip” or “jump” to the next appropriate question based on answer choices in the dichotomous key.
13. Conducted the second regional test, which included new participants and existing participants, to continue building the database for evaluating BMP effectiveness and improving protocol contents. Asked participants to compare the revised version of the Regional Protocol to the protocol they currently use.
14. Solicited additional specialized experts to assist in areas where the protocol was identified to be weak (e.g., fish passage). Worked with experts to develop additional questions within the protocol format, making sure each was based on scientific principles. Protocol developers must ask the appropriate questions to allow the expert to create the best questions that allow for the greatest technology transfer to the audience of users, while maintaining brevity.

Excerpt from the original protocol illustrating question progression and dichotomous key design. APPROACH A refers to the right side of the stream. An identical set of questions is provided for the left side (APPROACH B) of the stream.

27. APPROACH A. Which of the following best describes the soil movement for the slope distance outside the buffer? (Your answer will automatically take you to the appropriate set of questions)
    1. Sediment delivery to water body. (go to #28)
    2. Sediment was delivered inside the buffer and not to the water body. (go to #36)

3. Sediment moved outside the buffer and did not reach the buffer. (go to #42)
4. Soil stabilized outside the buffer. (go to #48)

IF SEDIMENT WAS DELIVERED TO WATER BODY
From outside buffer for approach "A"

28. What is the evidence that sediment was delivered to the water body from outside the buffer?
    1. Direct ditch or mineral rut termination at water body or high water mark.
    2. Gully terminating at water body or high water mark.
    3. Rill terminating at water body or high water mark.
    4. Sediment deposition trail or fan at water body or high water mark. (No channeling observable at high water mark)
    5. Sheet flows with soil slumping, dropping or soil puddling terminating at water body or high water mark.
    6. Mechanical addition of soil to water body or high water mark. (example; bulldozer pushing soil into water body)

29. What is the total length of rill, gully, ditch or rut? (Report in whole feet) (Enter "0" for sheet flow, mechanical addition or deposition fan.)

30. What is the mid point cross sectional area of the rill, gully, ditch or rut? (Report in whole square inches)

31. Measure the amount of sediment delivered to the water body, from outside the buffer in question #28 in cubic feet to one decimal. (Enter "0" if not measurable)

32. Which of the following best describes the type of sediment delivered to the water body?
    1. Organic material
    2. Silts and loams
    3. Sands
    4. Gravels
    5. Cobbles and stones

33. Will sedimentation continue to occur during the next storm event?
    1. Yes
    2. No
    3. Unknown

34. Which of the following activities was the primary cause of sediment delivery to the water body from outside the buffer?
    1. Trail or Road structure outside the buffer.
    2. Trail or Road maintenance activities outside the buffer.
    3. Lack of trail or road maintenance activity outside the buffer.
    4. Landing/Yard activities outside the buffer.
    5. Harvesting activities outside the buffer.
    6. Improper BMP application.
    7. Timing of operation due to soil and weather conditions.

8. Other land use activities outside of buffer.
9. Natural event.

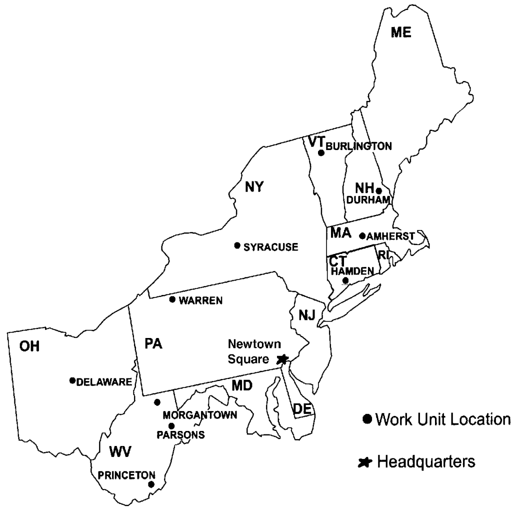
35. For question #34, describe the most likely reason sediment was delivered to the water body regarding application of BMP principles and practices? (Answer will take you to question 49)

1. Principles not applied. (go to #49)
2. Practice failed due to inadequacy or incompleteness of practice implementation. (go to #49)
3. Inadequate maintenance of practices. (go to #49)
4. Principle(s) followed and Practice(s) applied appropriately but failure occurred. (go to #49)
5. Trail or Road location does not allow for adequate water flow control. (go to #49)
6. Practice applied correctly but degraded by other land use activity. (go to #49)
7. Practice inadequately applied and degraded by other land use activity. (go to #49)
8. Other land use activities only. (go to #49)

Ryder, Roger; Edwards, Pamela J. 2005. **Development of a Repeatable Regional Protocol for Performance-Based Monitoring of Forestry Best Management Practices.** Gen. Tech. Rep. NE-335. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 15 p.

There has been a long-standing interest in improving Best Management Practice (BMP) monitoring within and among states. States monitoring the implementation and effectiveness of BMPs for forest operations take a variety of approaches. This creates inconsistencies in data collection and how results are reported. Since 1990 attempts have been made to develop a consistent BMP reporting methodology; the attempts have met with varying degrees of success, utility, and acceptance. Traditional monitoring focused on individual BMPs in terms of prescriptive guidelines, but this approach created inconsistent monitoring methodologies. To improve consistency and allow a more universal method for BMP monitoring, the approach to developing the protocol, described herein, focuses on the underlying "principles" which guide the design and applicability of BMPs. Shifting emphasis to the underlying principles facilitates outcome or performance-based monitoring of BMPs, which is a more universal, less subjective, and more direct means of evaluating BMP performance for protecting water quality. In turn, repeatability is improved. In this paper we discuss the development process and initial testing of a consistent repeatable BMP monitoring protocol for timber harvesting activities adjacent to water bodies. The protocol could be applied across much of the United States.

Key words: BMP effectiveness, underlying BMP principles, expert system, water quality, erosion, sedimentation, timber harvesting, logging, road construction, road maintenance.



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