BEYOND THE *GUIDELINES*: PRACTICAL LESSONS FOR MONITORING

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Abstract. A series of workshops have provided extensive feedback on a recently published manual, *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (Guidelines)* (MacDonald *et al.*, 1991). These workshops and other discussions have led to the identification of fourteen additional 'lessons' for monitoring. These lessons are concepts which either were not incorporated into the *Guidelines*, were not sufficiently emphasized, or which are needed to put the *Guidelines* in context. The topics include: monitoring as a continuum; defining objectives and hypotheses; peer review; uncertainty and risk; upslope *vs.* instream monitoring; photo sequences; scale considerations; data storage, data interpretation, and data base management; 'activities monitoring'; and personal commitment as a critical component in monitoring projects. Many of these lessons might appear self-evident, but our experience indicates that they are often ignored. Like the *Guidelines*, these lessons are widely applicable and should be explicitly recognized when formulating and conducting monitoring projects.

1. Introduction

In September 1991 Region 10 of the U.S. Environmental Protection Agency (EPA) and the Center for Streamside Studies (University of Washington) published a 166-page document *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (Guidelines)* (MacDonald *et al.*, 1991). Although the specific objective of this document was to provide guidance for monitoring the effects of forest management activities on streams, much of the information and many of the procedures are more broadly applicable. This, plus the relative dearth of other guidance-type literature, resulted in nearly 6000 copies of the *Guidelines* being distributed within five months. A second printing of 6000 copies was undertaken in spring 1992.

After releasing the *Guidelines* EPA convened $1\frac{1}{2}$-day workshops in Alaska, Idaho, Washington, and Oregon. The primary purpose of these workshops was to show resource specialists and resource managers how the *Guidelines* could help them design and execute monitoring projects. In early 1992 a fifth workshop was organized by the U.S. Forest Service in Missoula, Montana.

Approximately 550 people attended these workshops. Each workshop included lectures, individual exercises, case studies, and group exercises. These different components of the workshops provided numerous opportunities for questions and

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feedback on the *Guidelines*; in effect the workshops served as a non-structured validation process. This review by the target audience was quite different from the reviews provided by members of the Technical Advisory Committee during the preparation of the *Guidelines*, and the final review of the draft document by EPA and selected experts.

The workshops, other discussions, and our own subsequent work have led to the identification of a number of practical points essential to the development of successful monitoring projects. Many of these are included, or at least alluded to, in the *Guidelines*, but most of them were not sufficiently explicit or adequately emphasized given the needs of the target audience.

As many readers may not be familiar with the *Guidelines*, this paper first provides a brief overview of the *Guidelines* and accompanying expert system. This is followed by the fourteen practical lessons for monitoring which have been drawn from the workshops and other feedback on the *Guidelines*. It should be emphasized that these practical lessons are more generally applicable, and are not tied to specific geographic areas, management activities, or regulatory structure.

2. Overview of the *Guidelines*

2.1. Scope

The purpose of the *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska* is to assist people in designing water quality monitoring projects and selecting monitoring parameters. The term 'water quality' is used in the broadest possible sense, as the *Guidelines* consider not only the traditional physical and chemical constituents, but also those parameters which directly affect designated uses such as coldwater fisheries and recreation. A total of 29 different parameters were considered (Table I).

The *Guidelines* focus on forestry, but other land uses – such as mining, grazing, and recreation – are incorporated. This was necessary because the water quality at any given point integrates all land use effects and natural processes upstream of that location, and most forested catchments have a mixture of management activities. Similarly, the *Guidelines* emphasize the monitoring of streams and adjacent riparian areas, but recognize that the need to protect downstream lakes, reservoirs, and other water bodies may affect the design of a monitoring project and the selection of monitoring parameters.

2.2. Part I

Part I of the *Guidelines* sets out a procedure for designing a monitoring project and selecting the parameters to be measured. The first chapter discusses both the legal background for water quality monitoring in the U.S. and the rationale for monitoring. The varying objectives of monitoring projects beget different types of monitoring. Seven types of monitoring are defined in the *Guidelines*, and these are trend, baseline, implementation, effectiveness, project, compliance, and validation.

TABLE I
List of Monitoring Parameters.

Physical and chemical constituents	
	Temperature
	pH
	Conductivity
	Dissolved oxygen
	Nutrients
	Nitrogen
	Phosphorus
	Herbicides and pesticides
Changes in flow	
	Size of peak flows
	Low flows
	Annual water yield
Sediment	
	Suspended sediment
	Turbidity
	Bedload
Channel characteristics	
	Channel cross-section
	Channel width/width-depth ratio
	Pool parameters
	Habitat units
	Bed material
	Particle-size distribution
	Embeddedness
	Surface vs. subsurface particle-size distribution
	Large woody debris
	Bank stability
Riparian characteristics	
	Riparian canopy opening
	Riparian vegetation
Aquatic organisms	
	Bacteria
	Aquatic flora
	Macroinvertebrates
	Fish

The types of monitoring are distinguished largely by the purpose of the monitoring and the use of the data, rather than the specific data collected.

The first part of Chapter 2 shows how monitoring is essential to the effective regulation of water quality, and then sets out a step-by-step procedure for developing a monitoring project. These steps include: (1) define the general objectives and budgetary constraints; (2) collect existing information; (3) identify the specific objectives; (4) define monitoring parameters, sampling frequency, sampling location(s), and analytic procedures; (5) check that the proposed project will meet the specific monitoring objectives within the general budgetary constraints; (6) initiate the project on a pilot basis; (7) analyse the data and modify the project as necessary; (8) proceed with the revised project; and (9) periodic preparation of reports and recommendations (Figure 1). Feedback loops are essential to both the legal process and the development of a monitoring project, and some of the most important feedback loops are shown in Figure 1.

The statistical aspects of water quality monitoring are discussed in Chapter 3. Specific topics include statistical design, principles of sampling, and the principles of statistical testing. The trade-offs between sample size, variability, level of significance, and power are explained, and these four factors are combined to demonstrate the concept of Minimum Detectable Effect (MDE). Specific statistical procedures are not reviewed, but key references are provided.

2.2.1. Parameter selection

Chapter 4 lays out the process for selecting the water quality parameters to be measured. In the U.S., the legal basis for regulating water quality is largely built on the concept of maintaining and enhancing the 'designated beneficial uses' of water (EPA, 1988). Designated beneficial uses typically include domestic water supply, hydroelectric generation, coldwater fisheries, recreation, etc. Each state is required to designate the beneficial uses for each water body within its boundaries. Water quality standards are a combination of the designated beneficial use and the criteria necessary to protect that use (EPA, 1988).

Two of the basic problems in monitoring the effects of forestry activities on streams are: (1) sources are diffuse (i.e., nonpoint), and (2) forestry affects very few of the approximately 100 water quality criteria recommended by EPA (EPA, 1986). The only EPA-recommended criteria which forest management activities are likely to affect are turbidity, suspended solids, color, dissolved oxygen, and temperature. At least four of these five criteria are direct or indirect measures of sediment, but the direct determination of change in turbidity or suspended solids can be a very difficult task (Walling and Webb, 1981; MacDonald, 1992). This suggests a need for alternative measures of water quality, and this is largely why the list of parameters considered in the *Guidelines* is so extensive.

Alternatives to sediment monitoring include measures of stream channel morphology and aquatic organisms. These may offer considerable promise for monitoring (EPA, 1989, 1990; Cullen, 1991), but the data to establish specific criteria is

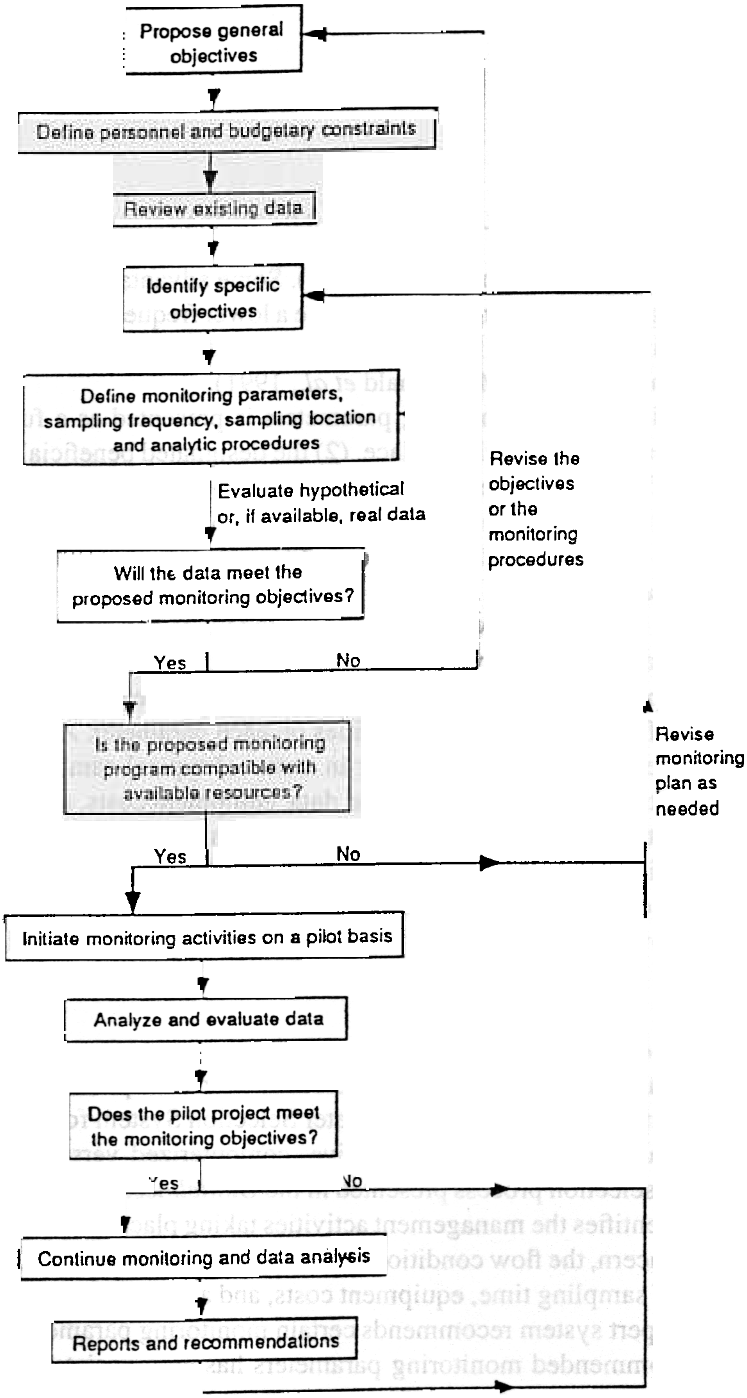

Fig. 1. Development of a monitoring project.

largely lacking (MacDonald *et al.*, 1991). Some advantages of monitoring channel morphology or aquatic organisms include a lower frequency of sampling, direct ties to a sensitive designated use (coldwater fisheries), and a relatively high sensitivity to forest management (MacDonald *et al.*, 1991).

The selection of monitoring parameters is presented as a function of: (1) the management activities taking place, (2) the designated beneficial uses, (3) whether there is safe access to the stream during high flow events, and (4) the costs associated with monitoring a particular parameter. Cost is further broken down into the frequency of sampling, the time needed to collect the sample or data, equipment costs, and analysis costs.

The 29 parameters evaluated in the *Guidelines* are qualitatively ranked with regard to each of these seven factors. The first table in Chapter 4 qualitatively ranks how each parameter affects each designated use. The next table indicates the effects of nine different management activities on each parameter. A third table evaluates the relative cost of each parameter in terms of typical sampling frequency, time necessary to collect a sample or field data, equipment costs, analysis costs, and the flow conditions which must be sampled. All of this information is then qualitatively combined into an overall evaluation of the usefulness of each parameter to monitor the effects of a specific management activity. By necessity these rankings are gross averages over a very large and diverse geographic area, and will not apply in all cases.

2.2.2. *Expert System*

The information contained in these tables has been incorporated into a PC-based expert system called PASSSFA (Parameter Selection System for Streams in Forested Areas). Basically this is an interactive, computerized version of the tables and parameter selection process presented in the *Guidelines*. After loading the program the user identifies the management activities taking place, the designated beneficial uses of concern, the flow conditions which can be sampled, and the cost constraints in terms of sampling time, equipment costs, and analysis costs. From this information the expert system recommends certain monitoring parameters. Although each of the recommended monitoring parameters has an associated confidence factor, the final list of recommended parameters must then be evaluated on the basis of existing data, local conditions, and professional judgement. Figure 2 illustrates the parameter selection process set out in the *Guidelines* and applied in PASSSFA.

2.2.3. *Other Considerations in Parameter Selection*

The final part of Chapter 4 briefly reviews how differences in the physical environment might affect the selection of monitoring parameters. Climate, land form, geology, and soils all alter the effect of a particular management activity and the sensitivity of a stream system to human disturbance. Such considerations must be taken into account when developing a monitoring project. The tremendous diversity of landscapes and streams within the Pacific Northwest and Alaska meant that

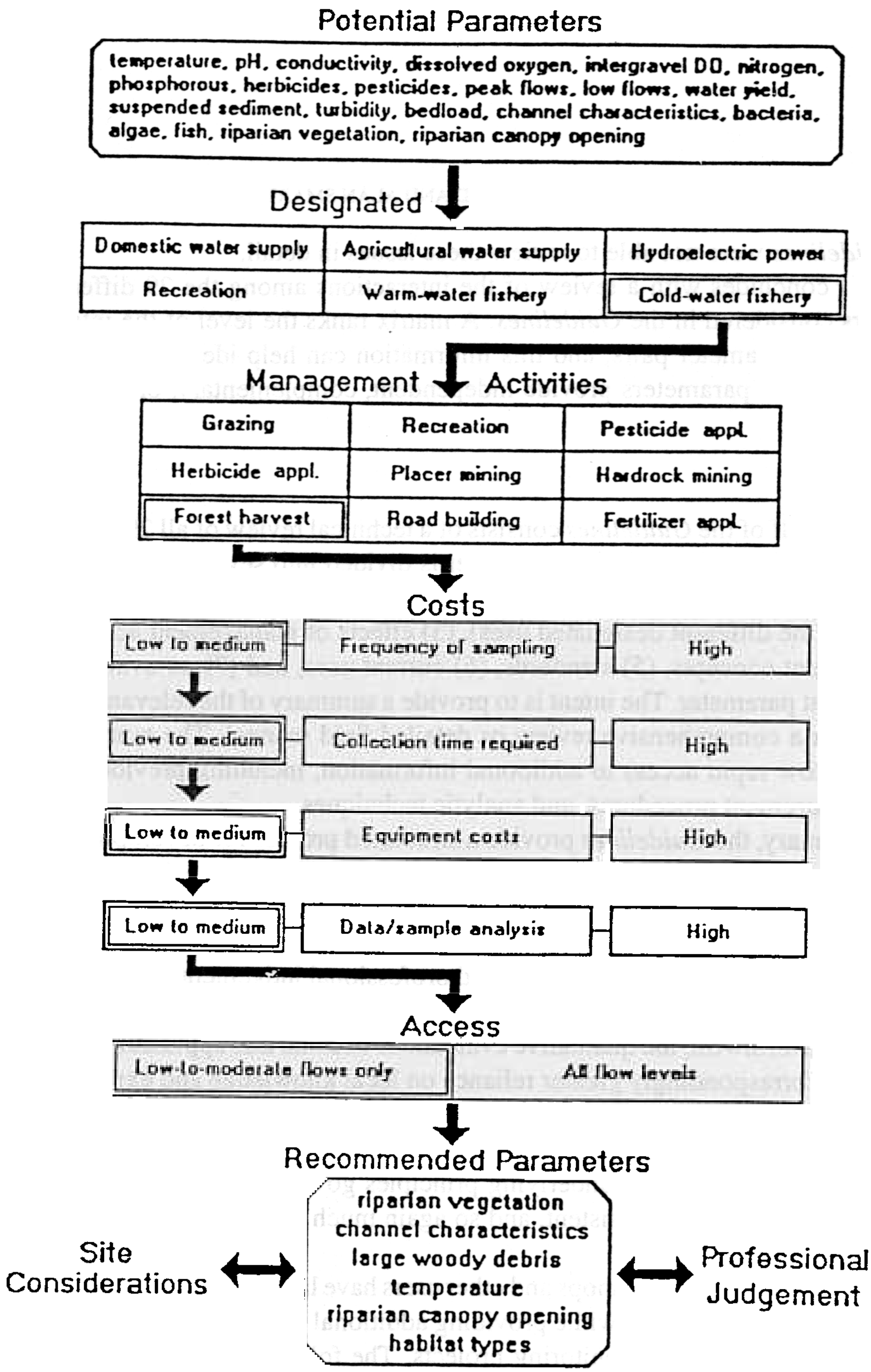

Fig. 2. Parameter selection process.

the *Guidelines* were not able to review these issues in detail.

Part I concludes with a review of the interactions among the 29 different parameters considered in the *Guidelines*. A matrix ranks the level of the interaction between all parameter pairs, and this information can help identify the extent to which different parameters provide independent, complementary, or overlapping information.

2.3. PART II

The larger half of the *Guidelines* consists of a technical review of all 29 monitoring parameters. The review of each parameter is divided into seven sub-sections, and these are: (1) definition, (2) relation to designated uses (i.e., how does that parameter affect the different designated uses), (3) effects of management activities, (4) measurement concepts, (5) standards, (6) current uses, and (7) an overall assessment of that parameter. The intent is to provide a summary of the relevant literature rather than a comprehensive review or detailed field manual. The numerous references allow rapid access to additional information, including previous studies, field measurement procedures, and analytic techniques.

In summary, the *Guidelines* provide a structured process for developing a monitoring project and selecting the parameters to be monitored. The basic process is applicable to much more than monitoring the effects of forestry on streams, and the wide distribution of the *Guidelines* confirms this view. However, the *Guidelines* are not a cookbook, and local knowledge and professional judgement must be applied when formulating a specific project. As one moves further away from forestry and the Pacific Northwest, the qualitative evaluations become less applicable, and there must be a correspondingly greater reliance on local knowledge and experience.

The *Guidelines* also provide a useful compilation of existing knowledge on the 29 parameters listed in Table I. Although this review concentrates on the Pacific Northwest and Alaska, the underlying principles governing stream behavior and aquatic ecosystems are consistent, and so again much of this information is more broadly applicable.

Feedback from the workshops and other users have largely validated the material presented in the *Guidelines* while providing additional insight into the problems of designing and executing monitoring projects. The following section summarizes the additional practical lessons which are worthy of greater emphasis.

3. Practical Lessons for Monitoring

The following practical lesson are listed because they will facilitate the successful design and execution of monitoring projects. Some of these are mentioned in the *Guidelines*, but deserve greater emphasis, while others were not explicitly included. Many of these points initially might seem self-evident or even trivial, but our experience is that these issues typically are given no more than tacit recognition. In many cases a monitoring project is well underway, and then one or more of these

Qualitative	Rigorous
Open-eye and open-mind monitoring	Statistically-sound design
"Walking in the rain"	Peer review
Low cost	Pilot project
Few, if any, quantitative data or results	Statistical data analysis
	High levels of QA/QC
	Careful documentation

Fig. 3. Continuum of monitoring.

issues emerges as a problem which was not fully resolved in the planning phase. Early recognition and resolution of these practical points should greatly enhance the efficiency of monitoring projects and their prospects for success.

3.1. CONTINUUM OF MONITORING

The *Guidelines* focus on the design of relatively structured monitoring projects which gather quantitative data. In many cases, however, informal observations, particularly during storm events, cna provide much of the information needed to guide and evaluate management activities. We should think of monitoring as a continuum, for monitoring projects can range from informal walking in the rain to carefully replicated, quantitative studies (Figure 3). Either of these approaches can be valid, depending on the objectives and context of the monitoring project. Informal walking in the rain – open-eye and open-mind monitoring – is limited in its applications by its subjective nature, but it can be extremely cost-effective. The more formal studies at the opposite end of the continuum are necessary to provide more detailed and defensible results. The learning benefits associated with an occasional walk in the rain and the direct observation of watershed processes should not be underestimated, as these can greatly facilitate the design of more rigorous monitoring projects.

3.2. UNDERSTANDING PHYSICAL AND BIOLOGICAL PROCESSES

A good monitoring plan is based on an understanding of the physical and biological processes operating within the catchment. To maximize efficiency, a monitoring plan must identify those parameters which are: (1) sensitive to the management activities of concern; (2) directly related to the designated beneficial use(s); and (3) capable of indicating management impacts (i.e., unlikely to be overwhelmed by confounding factors or the natural variability in time and space). The choice of sampling locations and the timing of the measurements must be guided by an understanding of the system in which the monitoring takes place. For example, it probably makes little sense to monitor channel morphology in a bedrock channel, or to use sport fish populations as indicators of adverse management impacts in areas subject to heavy fishing pressure. Suspended sediment data without accompanying discharge measurements are of little use. Monitoring intergravel dissolved oxygen may not be appropriate if fish populations are limited by rearing habitat rather than spawning habitat or food supply. Often we don't think through these issues, or else we make presumptions about stream ecology and physical processes which may not necessarily be valid. Any failure in understanding the system of concern reduces the likelihood that a monitoring project will achieve its objectives.

3.3. Monitoring in the Stream Channel May Have a Low Degree of Sensitivity

By definition, measurements in a stream channel integrate everything upslope of that point. Thus measurements in the channel often are a diluted version of what is occurring either higher up in the channel network, or on the adjacent sideslopes (MacDonald, 1989). From a practical point of view it's usually easier to determine the effects of roads on water quality by directly monitoring road drainage, rather than by monitoring water quality at a downstream location. Legally, sediment generated from roads may not be a concern until this sediment enters a designated water body and reduces water quality or impairs a designated beneficial use. For this reason there must be a clear physical linkage between the upslope or upstream measurements and downstream water quality.

One can argue that monitoring should stem from a sense of stewardship and a desire to minimize management impacts, and not just from the need to satisfy legal requirements. This approach supports the use of upslope and upstream measurements, and suggests less of a need to link these observations to downstream conditions. While the *Guidelines* recognized that monitoring within the stream channel may have a lower sensitivity than on-site monitoring, the huge number of potential monitoring techniques meant that on-site and upslope monitoring procedures were not explicitly discussed. A focus on upslope controls also ignores much of the legal basis for regulating water quality in the U.S.

3.4. Definition of Objectives

The conceptual process for developing a monitoring project was described earlier (Figure 1). Not every project will proceed exactly through these steps as presented in Figure 1. Most projects will loop back through certain steps, but the timing and precise order of these iterations will vary from project to project. Nevertheless, all the feedback to date has indicated that each of the steps shown in Figure 1 is essential. The application of Murphy's Law to monitoring means that any step that is skipped will inevitably generate problems later on.

It is the fourth step – identifying the specific objectives – which has been repeatedly identified as the most important and the most difficult. At each workshop small groups were convened to develop and review monitoring projects; about half the groups realized part way through that they had not clearly specified their objectives, and had to return to this step. Once the objectives were clearly stated, the groups typically found that the rest of the monitoring project would fall into place.

For example, a group might start with the objective of evaluating the effects of forest harvest on coldwater fish in some particular area. This type of general objective provides very limited guidance for setting up a monitoring project. However, if the objective is focused by identifying: (1) the limiting factor(s) for a particular fish species in a particular area, and (2) how management activities might affect that factor, then the objective prescribes the monitoring project. In this case, the specific objective might be to determine how forest harvest in the riparian zone is affecting the recruitment of large woody debris into the stream channel in low-order streams, as this is controlling the amount of rearing habitat for a specific fish species in a particular type of stream in a certain catchment, and the amount of rearing habitat is limiting the fish population of primary concern. This formulation of the objectives then leads directly to both the parameters to be monitored (e.g., large woody debris and riparian vegetation) and the sampling locations (e.g., second-order streams with extensive forest harvest). Definition of the monitoring parameters and sampling locations in turn define the frequency of monitoring (e.g., once a year). By defining the specific objectives people are forced to sharpen their thinking and resolve a variety of hidden conflicts. The recognition and resolution of hidden issues probably explains why the definition of the specific objectives is the most difficult step.

3.5. Definition of Hypotheses

Another means to focus the objectives and sharpen the design of a monitoring project is to explicitly define the hypotheses to be evaluated. This is an essential step if quantitative data are to be collected and statistically analysed. Defining the hypotheses *a priori* helps ensure that the experimental units and sample populations are clearly defined, and that there is sufficient replication to allow statistical testing. Because this is a challenging step, it is often ignored even though the objectives indicate that quantitative results are expected.

3.6. Peer Review

A major shortcoming of Figure 1 is that it does not explicitly recognize the need for, and benefits of, peer review. A monitoring plan developed by a single individual will reflect that person's experience and perspective. Asking one's peers to review a monitoring plan uncovers hidden assumptions and allows for the input of other viewpoints. This will greatly enhance the chances of success, and help build an interested constituency for the proposed project.

Formal or informal peer review also should be applied during data analysis, report writing, and the formulation of recommendations. Again an independent observer can add a perspective and insight that will help ensure that the data are properly and fully analysed, the conclusions are justified, and the recommendations are sound. Peer review does require more time, and constructive criticism is often difficult to accept, but after a few rounds nearly everybody realizes that unbiased peer review is a highly beneficial process.

3.7. DATA STORAGE AND DATA BASE MANAGEMENT

Another limitation of Figure 1 and the *Guidelines* is that data management needs are not explicitly addressed. Often monitoring projects are initiated without recognizing the amount of data that will be generated. For example, a project that measures eight common parameters (e.g., discharge, pH, conductivity, nitate-nitrogen, total nitrogen, total coliform, total phosphorus, and suspended sediment) at ten locations on a weekly basis will yield over four thousand pieces of data in a single year. Organizing and analyzing such large data sets is not a trivial task, and to this must be added the error-checking, replicate sampling, and replicate analyses which are necessary for quality assurance and quality control. The rapid increase in computer hardware and software capabilities is facilitating these aspects of monitoring, but data management and analysis procedures should be explicitly addressed during the design phase.

3.8. UNCERTAINTY AND RISK

Monitoring projects take place in complex and changing environments, and that limits the extent to which the results can be predictable or definitive. In many parts of the Pacific Northwest, for example, low-order stream channels are subject to highly disruptive events such as debris flows and the breaking of debris dams (e.g., Swanson *et al.*, 1987; Benda, 1990). The occurrence of these periodic natural events may overwhelm the more frequent but smaller changes due to management activities. Lisle (1982) found that stream channels in Northwestern California were still responding to the 1964 flood fifteen years later. The capability to detect man-induced change depends largely on the magnitude of the management impact relative to the natural variability. In many cases we don't have long-term data to evaluate the natural variability, nor can we predict the occurrence of future events.

This means that monitoring always will be operating in the realm of risk and uncertainty. A specific set of management activities can have relatively minor effects under one set of climatic events, and much more adverse effects under a different set of climatic events. Similarly, the ability of a monitoring project to detect management impacts depends on: (1) the natural events occurring during the monitoring period; (2) the synergism between natural events and management effects; and (3) the extent to which the monitoring period is representative of longer-term conditions. Often there is little which can be done to resolve these issues, but it is important to recognize them up front and indicate to managers the uncertainty and risks associated with both monitoring projects and management activities.

3.9. DATA INTERPRETATION

Another aspect of uncertainty is the limited extent to which any set of monitoring data provides a true and complete representation of the system being monitored. We can't measure everything everywhere, yet monitoring projects are trying to assess condition over time and identify the cause(s) of any observed change. The limited budget of most monitoring projects and the complexity of natural systems means that inferences are being drawn from limited data. Add in the problems of missing data, lost samples, and other applications of Murphy's Law, and this suggests a need for overlapping or complementary data.

Often people presume that measuring a single parameter will provide the necessary information to both identify change and to link that change to management activities. There is a natural desire to simplify the behavior of stream systems, and to look for magic bullets or tools. The reality is that such tools don't and almost certainly won't exist. Hence monitoring projects have to make an explicit trade-off between ambiguity and uncertainty on the one hand, and the costs of collecting more data in order to achieve a better and less ambiguous result. To a large extent this choice is a function of the objectives and needs of the monitoring project.

3.10. PHOTO SEQUENCES

One useful monitoring technique not discussed in the *Guidelines* is photo sequences. A series of photos taken over time at the same location can help document changes which may not be apparent from regular visits to the site. Even if these photos are not used directly as a monitoring technique, a photo sequence can be an extremely effective communication tool (e.g., Clifton, 1989; Megahan *et al.*, 1992).

3.11. SCALE CONSIDERATIONS

A critical question in developing a monitoring project is the selection of monitoring locations. For non-reactive physical and chemical constituents there is greater dilution with increasing watershed size, and this diminishes the magnitude of change resulting from upstream activities. This principle is widely recognized, yet the concept is rarely applied when designing monitoring projects. In additon to the problem of dilution, both sediment and water are stored in the stream channel (e.g., Megahan, 1982; Hunt, 1990), and this further diminishes the detectability of management impacts in the downstream direction (MacDonald, 1989, 1992). Hence the results of a monitoring project may be partly preordained by the placement of the monitoring site, and these scale considerations need to be explicitly recognized when formulating a monitoring project.

3.12. Monitoring of Management Activities

An alternative to monitoring the effects of management activities on water quality is to directly monitor the implementation of the management activities. In other words, it may be simpler and more cost-effective to monitor the way in which individual operations are carried out on the ground as opposed to detecting changes in water quality.

Other advantages of monitoring management activities on site include: (1) problems are discovered earlier, thereby reducing their potential impact and allowing corrective measures to be taken, and (2) individual operators become more aware of what is required, and this should help reduce the frequency and magnitude of future problems. This monitoring of management activities is closely allied with implementation monitoring – commonly defined as 'Did we do what we said we were going to do?' – but is done during the operation rather than after the fact. Both implementation monitoring and what might be termed 'activities monitoring' can be very cost-effective and provide good resource protection. The specifics of such procedures were beyond the scope of the *Guidelines* because they vary by agency, operator, and management activity.

3.13. Learn from Past Projects

Rarely, if ever, are monitoring projects initiated in an area where there is no prior information or experience. Even if quantitative data are not available, long-term qualitative observations can provide invaluable guidance. It is suprising how often a few questions will lead to the discovery of previous monitoring efforts which were never completed or written up. Talking to the people involved can provide useful guidance on sampling locations, data collection techniques, and natural processes. The point is that you can learn just as much from unsuccesful as successful projects, and it is encumbent upon the people designing a monitoring project to initiate such discussions. By avoiding previous problems each subsequent project will at least learn something new, even if it may not achieve the original objectives. In this way the resources allocated to monitoring always should yield some positive result.

3.14. Commitment

One theme that slowly emerged from the workshops was the direct correlation between the success of a monitoring project and the commitment of the people involved with the project. The most successful projects always included one or more people with a level of commitment that extended well beyond a simple institutional responsibility. The motivation for this higher level of commitment can stem from a variety of sources, including a high level of concern for the resource, scientific curiosity, or a desire for professional recognition and advancement. Recognizing and building in a high level of personal commitment is one of the most important ways to ensure that a monitoring project will be successful.

4. Conclusions

Monitoring is not a trivial task. Often monitoring is an afterthought to the management activities and allocated a modicum of resources. Many times there is an underlying belief that making regular measurements of a single parameter at a couple of locations will permit the detection of change due to management activities. In fact, monitoring takes place within a dynamic and complex environment. Monitoring is becoming a required component of management activities, and monitoring data are necessary to justify the public and private resources being spent on water pollution control efforts. Hence there is a need for specific guidance on the design of monitoring projects, and some of the most useful documents (e.g., Ponce, 1980a,b; Kunkle *et al.*, 1987) are either out of print or not readily available.

The *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska* (MacDonald *et al.*, 1991) provides a process to help design monitoring projects and select monitoring parameters. Much of this information is more generally applicable, and a series of workshops and discussions have identified some concepts which were not adequately covered in the *Guidelines*, or which were needed to put the *Guidelines* in a broader context. We hope that the fourteen practical lessons presented here will provide additional guidance to those responsible for monitoring management effects on natural resources.

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Note

Copies of the *Guidelines* can be obtained at no cost from U.S. Environmental Protection Agency Region 10, NPS Section WD–139, 1200 Sixth Street, Seattle WA 98101, USA. Copies of the expert system (PASSSFA) can be obtained by sending a MS-DOS formatted diskette with at least 250K of available storage to the same address.

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