TIMBER FISH AND WILDLIFE

AMBIENT MONITORING PROGRAM WORKPLAN

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EXECUTIVE SUMMARY

In response to the Timber, Fish, and Wildlife (TFW) mandate for statewide resource information, the Ambient Monitoring Steering Committee (AMSC) has developed a monitoring program to guide the collection, analysis, and interpretation of information on the status and trends of resources in the forest lands of Washington. The workplan outlines the goals, rationale, and approaches that constitute this monitoring program, and describes the means by which AMSC will aid TFW cooperators in its implementation. The workplan reflects the efforts of numerous individuals who contributed to discussions on the topic of monitoring as it pertains to TFW, and represents a substantial revision of the initial draft workplan dated October 1988. The following overview summarizes pertinent features of the revised workplan.

There are two major elements of the AMSC monitoring program. The first of these is a landscape classification system. This system is based on the theory of the physical processes that shape the character of streams and the landscape through which streams flow. The classication system is being developed to further our understanding of why streams look the way they do in order to account for as much natural variability as possible before we begin to try to understand effects of forest practices on fish, wildlife, and water quality. The classification system will also provide a framework within which monitoring data can be gathered, analyzed, and applied in the most useful and efficient manner possible. If successful, our approach to viewing the landscape through a classification system will enable us to establish critical links between physical features of streams and their biota.

The second major element of the AMSC program entails the establishement of a statewide program to provide data on resource status and resource trends. This program describes both a short-term strategy for implementation of the first year's sampling and a longer-ranged strategy for developing an extensive monitoring system. This program identifies two sets of variables that are likely to be useful to TFW. The first set of variables contains those that will form the foundation of a future, more extensive monitoring program, including some that will be used to verify and refine the proposed classification system. These variables are likely to be broadly useful to TFW and are to be measured statewide during the upcoming field season. A second set of variables, organized into 8 "modules", are likely to be measured only when more detailed information is desired for a particular topic.

AMSC recognizes that in order for resource information to be truly useful in the development of land-use practices that optimize protection, enhancement, and utilization of the multitude of natural resources in Washington's forests, the types of information gathered must suit the needs of managers, regulators, and policy-makers. These three decision-making groups operate on different timeframes and at different spatial scales ranging from short-term and localized (managers) to long-term and regional (policy-makers). Because of the differing information needs of these groups, the AMSC program was designed to include data useful at both statewide and local levels.

In addition to these decision-makers, who are the ultimate users of the resource information gathered through the TFW monitoring effort, there are three other principle groups that will be responsible for collecting, analyzing, and interpreting the bulk of the information. Each of these interrelated TFW data-gathering groups has their own specific set of information objectives. The first of these groups is AMSC itself. AMSCs interest lies in developing a very broad (statewide) progam that will generate data useful to a wide variety of users for a number of interests, most especially those within TFW.

A second group of "investigators" is made up of the individual projects within the TFW steering committees. The research conducted under these projects is likely to be intensive and sharply focused on fundamental environmental relationships. Some of the variables studied or methods used by this group are likely to be uncommon or even unique, and as such these variables would not necessarily be included in a broad-spectrum monitoring study such as outlined in AMSCs monitoring program. The results of these TFW committee projects may well provide new variables or improved methods for use in a later versions of the monitoring program.

The third group of data gatherers is composed of what are collectively referred to as "the cooperators". Within this group are tribal, government, and private interests that are interested in measuring a tremendous variety of things. Many of this group simply desire to know the extent and status of their resources in the most basic and general terms. The diversity of variables under consideration by these three groups underscores a point that AMSC wishes to make very clear: The AMSC monitoring program does *not* require that *everything be measured by everyone*. The program *is* designed to guide the data collection for many important variables that will be broadly useful to TFW when integrated through a classification system.

In return for the cooperation of these data-gathering groups, AMSC offers to train the field personnel in proper data collection, and will serve as the coordinator of these projects. Also, AMSC will 1) serve as the repository for the information we have asked the cooperators to collect, 2) analyze the data in the context of the AMSC program, and 3) use the results to modify and refine our monitoring program. This refinement will mean including new variables and methods as well as the rejection of older ones prior to the next field season. Ultimately, the information gathered over several years by many scattered research and monitoring projects around the state will be integrated through AMSCs efforts and especially through the land-aquatic classification system. This integrated information can then be used to develop cause-effect relationships, site-specific management options, and better overall forest practices.

Because of the ultimate importance of the classification system in making our efforts worthwhile, AMSC requests that all cooperators, in designing their field sampling programs, identify their study sites through this classification system (i.e, anchor their studies to the landscape vis a vis the classification scheme.). As with the pilot monitoring program, the classification system is presently far enough along in its development that AMSC can supply the methods necessary to use the system for the 1989 field season. Also, like the pilot monitoring program, the preliminary classification system will be extensively refined as information is gathered and as the integrity of each level in the system is tested. The specific data set needed to perform such tests will mean that data collectors can expect to see AMSC request collection of these variables in addition to those requested for the monitoring component, during the upcoming field season. AMSC will be hosting a workshop for the purpose of generating key variables for use in the establishment and testing of the classification system.

So, prior to this year's sampling season, AMSC will provide a list of key variables that we believe will be critical to the success of the TFW initiative, and therefore must be collected by as many cooperators as possible. Before we can provide this list, however, AMSC needs the input of TFW research committees. While AMSC has been developing the monitoring program, other TFW committees have been focusing on the very issues that constitute AMSCs module topics. For this reason, AMSC is soliciting the aid of TFW and other experts in identifying the variables and methods that are felt to be fundamental to an understanding of specific topics relative to TFW and monitoring.

AMSC realizes that refinement of our monitoring program or further development and testing of our classification system cannot proceed haphazardly with data from many scattered projects. To remedy this, we have initiated our own research projects to look at specific issues within each aspect of our program, and we intend to collect necessary information where others are not planning to work or where resources do not permit collection of even the minimal amount of fundamental data we advise. In fact, we anticipate that the sum of the variables suggested by yourselves, the other steering committees, and outsiders, will overwhelm most field investigations. Because of this we ask that when developing a list of variables for use by AMSC, they be prioritized in a manner that reflects the utility of each variable, from general to specific, in the context of monitoring. For example, if fish were a concern, and life history stage, substrate size, and stream temperature were listed as key variables that should be measured, the list might be ranked with substrate size first, followed by stream temperature and then life history stage to reflect the probable utility of the variables to groups with interests other than fish. By doing this, either AMSC or individual field study designers can decide which of the top variables they can reasonably gather information on, and which to do only if they have extra time or funds.

In summary, AMSC will compile a list of variables using the combined expertise of the whole of TFW for use in this summer's field season. This list will understandably be limited, owing to the preliminary nature of the monitoring program. Nonetheless, by the way the program is constructed, the information gathered during the upcoming field season, and in all subsequent seasons, will be fully utilized to improve AMSCs fledgling program.

TIMBER FISH AND WILDLIFE AMBIENT MONITORING PROGRAM WORKPLAN

INTRODUCTION

The TFW agreement involved two major changes in the way in which forest resource management decisions are made on state and private forest lands within the state of Washington. The first of these is known as "cooperative management" which simply stated means that the parties involved in natural resource management have committed to try working out their conflicts in a spirit of cooperation and problem soving rather than through confrontation. Given the wide range of goals and directives of the parties involved, and the history of lack of cooperation and hostility that have surrounded forest management issues, this is no easy task. In order to facilitate this process of cooperation, the parties agreed that the best way to improve decision making and avoid resource management based on opinion and position was to develop a cooperative monitoring, research, and evaluation program to guide future management decisions. This concept, the second major change in decision making, is known as "adaptive management". Adaptive management embodies the concept that management decisions, and their effects on the environment, can provide a basis for improving future management decisions if they are carefully evaluated. By learning from our mistakes and benefitting from our successes, management becomes a flexible tool which is not set in stone and which, like democracy, embraces well designed incremental change rather than periodic revolution.

Cooperative adaptive management has at least six politically important traits:

1. It allows actions to proceed in the face of uncertainty and potential opposition;

2. It facilitates communication among traditional adversaries and trust through cooperation;

3. It encourages adversaries to suspend conflict as they jointly develop ways to learn from experience;

4. It focuses attention on significant uncertainties, a strategy that should lower long term costs while raising the probability of protecting the ecosystem;

5. It organizes the collection and validation of information essential for making informed management decisions;

6. It focuses decision making on carefully collected and relevant resource information rather than the position or opinion of resource advocates respective political interests.

The TFW Agreement also recognized that there is a need to move decision making to a more site-specific level. While broad standards and regulations are necessary to provide management direction, many of the decisions which directly affect forest resources are made at a site-specific level. The diversity of local conditions makes it difficult or impossible to encompass all possibilities within a regulation. This concept has the benefit

of allowing site-specific flexibility to accomplish resource protection goals while not penalizing forest managers for problems found in other geographic areas.

Cooperative adaptive management , as developed for TFW, involves a number of management processes which are new to state level forest resource management in Washington. The most obvious examples of these are interdisciplinary (I.D.) teams which allow improved site-specific decision making, resource management plans which allow watershed or regional planning, and annual statewide TFW program reviews. The agreement also calls for instituting resource goal setting risk assessment, and subsequent monitoring and evaluation as a way to address concerns regarding cumulative effects. Each of these processes can , and are expected to, benefit from the information gathered in the cooperative monitoring, research, and evaluation program. While instituting these new processes, the traditional responsibilities for overall review , adjustment, and implementation of forest practice rules and regulations still lies with the Washington Department of Natural resources and other state level decision making bodies. The responsibility for management of other forest associated resources such as fish, wildlife, and water quality, rests with other agencies.

In order to meet the varying needs and expectations of resource managers, it is necessary that the research and monitoring programs be coordinated and conducted in a way which integrates these collective needs. It is important that the TFW monitoring and research program clearly states the type of information to be obtained from the various program projects and how the resulting information might be used by managers to enhance the decision making process.

The information needs and expectations of resource managers varies depending on which management process they are involved in. A TFW cooperator involved in an I.D. team would require very specific information regarding the resources in relatively close proximity to where the management action being reviewed by the team is to be conducted. A manager involved in overall TFW program review or review of state-wide forest practice regulations will have little need to know about local conditions at any given spot. He/she would take a broader view of the overall performance of the management program across the state. This view however must relate directly to the local view in order for changes made at the state level to correct problems which are directly experienced at the local level. In each case the manager has need for concise, interpretable, and useable information which help answer the question at hand. Thus, it is our view that the adaptive management program must be responsive to these differing but valid management perspectives and do so in an efficient, reliable, and cost effective manner.

There has been some confusion about the meaning of, and distinction between, research and monitoring. Research is defined by Websters as "careful, systematic, patient study and investigation in some field of knowledge , undertaken to establish facts or principles." Monitoring stems from the Latin word monere, " to warn". In the traditional resource management sense, this word is used to mean the periodic inventory and assessment of the status of some variable or resource in order to detect change or trends. Monitoring could conceivably be applied to a very specific geographic area or be established to cover broad regions. It could monitor one variable or many, and be designed to monitor the effects of some particular activity or determine the overall status of a resource.

There is no clear distinction between the general concepts of research and monitoring. Each must be carefully designed, each must be systematic, and each is undertaken to test

assumptions and establish facts or principles. As previously mentioned, a monitoring program could focus on specific areas and be designed to test the response of one specific variable to a specific management action. In this case the monitoring activity is conducted in support of a research program designed to establish a cause and effect relationship. However, monitoring may be conducted to establish resource or variable status, in which case it could not clearly be considered research.

It is important that TFW Cooperators recognize this overlap in terminology, but at the same time not be confused by it. What is important is that the entire research and monitoring program comes together to provide the appropriate information to the appropriate persons involved in resource management.

We believe that the proposed Ambient Monitoring Program meets this broad mission and further, that it provides a framework for guiding research, monitoring, and evaluation in a manner which is valid, comprehensive, and coordinated. By focusing on developing a statewide program, the ambient monitoring plan provides a unified working backdrop on which resource information can be gathered , interpreted, and used.

PROGRAM GOALS

Recognizing the TFW emphasis on developing a cooperative adaptive management system, the Ambient Monitoring Program has identified the following goals:

1. Support the TFW Adaptive Management system through the development of a monitoring system which provides data on resource status and resource trends. This monitoring system is designed so that information which is collected may be used for a number of TFW management actions including resource management plans, identification of corrective action projects, management for cumulative effects, identification of resource goals (as called for in the cumulative effects section of the TFW Agreement), analysis of effectiveness of TFW program (annual reviews), forest practices revisions, interdisciplinary team decision making, and site-specific prescription effectiveness assessment.

This goal is further defined and elaborated in the monitoring section of this plan.

2. Recognizing the TFW adaptive management program involves both research and monitoring, develop a monitoring system which is compatible and complimentary to the research efforts undertaken.

3. Since the concept of monitoring involves resource assessment across the state in both natural and managed environments, and is intended to give an accurate picture of the status of the statewide environment at a number of spatial scales, the ambient monitoring program will develop a landscape classification system as a conceptual framework that allows interpretation of information collected through both the research and monitoring programs.

PROGRAM RATIONALE

Information Needs

As described earlier, the TFW cooperative adaptive management system is concerned with improving decision making at a number of levels. We believe that an understanding of the needs and expectations of the various users and managers of forest resources is vital to the formulation of an effective monitoring strategy. Although any such description of needs will always involve some simplification, we believe the following are categories of personnel requiring information and the spatial and temporal scales they are most interested in. These categories are useful as a guide to evaluating the usefulness of each aspect of the monitoring program. Each of these general groups of persons are involved in management at different levels. They not only have different mandates but they are often interested in different spatial and temporal scales.

Managers. These are persons involved with on the ground decision making regarding one or more forest practices or the management of one or more forest resources such as fish, wildlife, and water quality. They are charged with carrying out the goals and objectives of their respective agencies, industries, or other rights or interests. They are involved with I.D. teams, layout of roads and timber sales, management of a local wildlife population, etc. They are basically charged with the day to day decision making regarding some resource in very specific areas being managed. Persons included in the category include representatives from private industry, agencies, tribes, and the public.

Managers, to various degrees, are charged with the planning, design, oversight, and implementation of individual actions at very particular locations. In the example of a DNR proprietary forester, this individual must plan and design specific timber management practices such as harvest, road building, etc. A tribal biologist may be involved in an I.D. team process in which they are expected to make a recommendation on a proposed forest practice.

These actions may take place within a larger geographic area of interest to an individual. For example, a tribal biologist may have responsibilities which encompass a watershed or several watersheds. A DNR employee may be working within a region, etc. However, these persons are responsible for the management of resources in a defined area and the management of these resources is in essence a series of individual, identifiable management actions. The specific status of local resources and local environmental processes is of major importance.

As described earlier, the TFW Agreement encourages site-specific decision making. Support of the principle is an important part of the monitoring program.

Managers are concerned at several time scales, however they have a very definite need to understand the current condition or status of the resource(s) of concern. That is, they need to know what resource they are working with, its condition, and it's magnitude. They also have a need to put their knowledge of the current status of the resource in the context of the general trend or status of that resource. For example, a fisheries biologist may have a thousand fish which means one thing if that number is up from a population of ten at the last count, and something quite different if that is reduced from a million. A forest manager need to know approximately the current status of his timber stands and needs to put this in perspective of the overall trend in the status of these stands. Thus, for

managers there are needs for information regarding the current, past, and likely future status of the resource they are managing in a particular area.

Regulators. These are persons charged with the implementation and enforcement of standards, laws and regulations. These laws and regulations deal with a number of resources and may at times be contradictory to other laws and regulations. Their overall objective is to see that standards are met. Examples of regulators are DNR and other agency enforcement persons.

Regulators are concerned with individual and cumulative management actions. Thus they are involved in very site-specific management as in the case of a Washington Department of Fisheries Habitat biologist responsible for conditioning and issuing/denying a hydraulics permit., or a DOE water quality inspector. The actions over which they have permitting or regulatory authority may also extend to broader regions such as watersheds or regions, however, generally the burden of regulation enforcement often falls to a local area or specific action.

Regulators generally are most interested in the current status of the resource or the likely status after a particular management action. They need resource status information to compare against the standards set by the regulations which they are charged to enforce. In general, they have less interest in the prior or long term future status of the resources.

Policy Persons. These persons are charged with determining standards, laws and regulations which are implemented by regulators and, in a less direct sense, by managers. These policy persons also may be involved in the establishment of goals and objectives of agencies, tribes, industries, and public groups. Examples of policy persons are representatives from industry, agencies, tribes ,and the public who serve on the TFW Policy Group. Another example would be the Forest Practices Board.

Policy persons are usually involved in the setting of policies which affect broad area such as the state. Although their policies are implemented at the local level, they themselves are usually not involved in management of specific actions but rather are interested in the overall affect of their policies. For example, the Forest Practices Board is interested in state wide regulation and policy and must only try to take very local conditions or need into account relative to the bigger state wide picture.

Policy persons have, in general, a major interest in the long term status of resources and somewhat less interest in the exact current status of that resource. The policies they set are often in place for extended periods of time and are not always easily change. These people are instrumental in guiding the future status of one or many resources.

It should be stressed that these are just generalizations and that we have drawn indistinct lines between them. However, the range of interests and foci of persons involved in forest resource management is very real and must be recognized in designing a monitoring program. To the extent possible or practical, the information generated through the monitoring program must meet the needs of each of these groups or emphasize one or more categories.

These differences in mandate, time and locational scale have very significant implications in the design and implementation of a monitoring program:

1. The manager is interested in measures of the resource available in a given area and the trend of this resource expressed in the same terms. A timber manager wants information on stand size, location, species types, age of stand, stocking density, etc. He will also require information which may affect his ability to manage that stand such as soils, slope, and access. A wildlife manager may want much the same information over the range of wildlife of interest. In this case the information is interpreted in terms of habitat use and requirement of wildlife; whereas the timber manager may take the same information and interpreting it in terms of board feet, cost of harvest, and gross and net profit. A fish habitat manager wants information on aquatic habitat types and condition in the area subject to management and within the range of the fish he is managing for. This information is interpreted in terms of it's ability to produce fish. In the above cases the information collected is determined by the parameters chosen by the manager as true indices of resource production. The information must be accurate, site-specific, and consistent with the information for the total area under management. There needs to be some flexibility in defining what these parameters are as they reflect local differences in the emphasis of the local managers interest.

Managers need site-specific resource information as well as an overall picture of the resource under the geographic area of their management authority or interest. A fish biologist needs information on the habitat to be affected as well as a perspective of how this habitat relates to the entire stream or watershed. A wildlife manager wants to know what kind of habitat is to be altered and that habitat types general occurrence, abundance, and location in the area.

Managers have need for a current picture, or inventory, of the resources they manages. They also need information collected over time, i.e. monitoring, to determine the trends in the status of the resource they manage.

2. The regulator's interests are generally confined to the parameters specified by the regulations or laws they are enforcing. These include such things a state water quality standards, riparian management regulations, etc. These parameters are generally inflexible and well defined; however they may have little in common with the conditions the manager is managing for.

The regulator focuses on site-specific information and performance juxtaposition with which he can determine if regulations are being met.

Regulators use site-specific information which represents the status of the resource at one point in time. Few regulations deal with long range goals, with some exceptions.

3. The policy person mixes the wishes of managers, the regulatory constraints, and political realities in order to change policy and regulation to try to accomplish an equitable, or at least workable, compromise where differences occur and to accomplish common goals where possible. Thus policy-makers take information used by both regulators and managers, along with other information (research, opinion, gossip) and make decisions. They have a need for information gathered at local levels to be pulled together in a more global picture. This global picture becomes a decision making tool in itself and the meaningfulness of the original data can be largely lost or become unimportant.

The policy person wants the big picture and has little need to deal with site-specific, detailed information except where it is symptomatic of management problems.

Policy makers traditionally do not need information about a resource condition at any on time, but are instead interested in average conditions longer periods of time such as months, years or decades.

These general trends in the types of information needed have to be recognized and accommodated in the monitoring program.

One final, but common, need of resource managers is for accurate predictive tools which allow the estimation of management effects prior to the management action. These tools need to be sensitive to local conditions and to provide a means for comparative risk assessment.

PAST PROBLEMS

The concept of using research and monitoring information to guide management is not a new one. Managers of resources often use monitoring and inventory information to aid in their decision making. Fisheries harvest managers monitor the status of fish stocks in marine waters to plan their harvests. They use data from past monitoring to refine their ability to predict the results of their management actions. Foresters make use of much the same process. While we have done a fair job in the management of specific resources, we have done a much poorer job of putting this technique to work for the management of multiple resources produced by the same environment.

There are a number of reason why monitoring and inventory information hasn't become more widely used and useful in multiple resource management and in the management of aquatic resources. In particular:

1. Aquatic and terrestrial resource information is difficult, time consuming and expensive to obtain.

2. There has traditionally been an inability or unwillingness to take the knowledge gained from one geographic area and apply it to another.

3. Different data collection methods are often used making direct comparison between areas difficult or impossible.

4. There has often been disagreement on what features of biologic communities, habitat, or water quality need to be measured.

5. Much data is collected without a clear idea as to how it is to be used or why it is relevant.

6. Once data is collected it is difficult to use and interpret due to the volume of information which is usually collected in order to characterize an area.

7. There has been a general lack of coordination in data collection efforts, often due to the fact that different agencies or parties collecting information have different needs and intended uses of the information. These may be due to the different types, scales, and time frames need as discussed in previous sections of this paper or may

due to different mandates of agencies, differences of opinion as to what defines habitat, etc.

8. The relationship between habitat quantity and quality and fish or wildlife production is difficult to establish and is likely not linear.

9. Poor quality of data.

10. Lack of usefulness, usability, or relevance to the manager.

11. There are often institutional barriers to the use of information and monitoring and research programs are not well integrated into the management system.

Each of these problems is significant and we must recognize that without dealing with these problems directly we risk the failure of TFW monitoring efforts and potentially the TFW adaptive management program altogether.

We believe the program we have developed address the issues raised and described thus far in this document. We further believe that it is critical that the monitoring and research program identify and be responsive to these issues so that our efforts are successful.

APPROACH

This section describes:

1. The general approach we have taken to both answer the needs identified by TFW for monitoring information and;

2. To best address the issues and past problems identified in the earlier portions of this document. We have tried to design a system which can fill the differing information needs of resource managers as we have identified them.

We have divided the ambient monitoring program into two main interactive components, monitoring and classification. Each of these components addresses elements of the issues we have described and each is a significant undertaking in terms of time and effort needed to develop this program and ensure it's success.

The monitoring component deals generally with developing what would traditionally be considered a monitoring program including :

1. Parameter selection - What will we monitor?

2. Identification of field methods - How will we monitor?

3. Sampling strategy - When and where will we monitor?

4. Coordination of field efforts - Who will do the monitoring?

5. Information management - How will information be put into useful form?

The classification component is intended to provide a means of describing the physical environment of Washington at a number of scales. These scales range from large regions of relatively homogeneous physiography (ecoregions), to sections of stream channel of relatively homogeneous physiography (stream segments). This "classification" system is intended to:

1. Provide a working "model" of physical processes that determine the structure and function of aquatic and terrestrial habitat features. This will lead to an understanding of natural variability and development of predictive capabilities.

2. Establish a standard of reference for biological work by providing a physical model of major processes which determines habitat type, quantity and quality.

3. Guide the monitoring sampling scheme by stratifying the physical landscape in a useful way.

While we are separating these two elements for the purposes of identifying work tasks and for program planning, they are really quite related and interdependent. We believe that conducting a monitoring program without the benefit of a well conceived classification system will likely not succeed in meeting the needs and expectations of the TFW adaptive management system. Classification provides a way of describing and stratifying the environment into units which we believe are identifiable and interpretable. That is, we expect to be able to explain why a particular stream type looks the way it does (in physical terms), and make some determination of the factors influencing that unit. These influences may be natural or management-induced. Monitoring provides the data to characterize these units. With this information we can test, verify or change the classification. We may also collect information regarding the physical variables which we feel have the greatest influence on biological resources, and collect information on the status of these biological resources themselves. This information will be used to begin to relate biological status with physical habitat status and interpret what factors are most influencing the system. It will then be possible to make well informed decisions regarding the effects of our management activities and guide changes to this management if resource goals are not being met.

This overall approach will also allow us to avoid or lessen the problems we have previously mentioned. Specifically:

1. By providing a stratified hierarchical system of identifying major aquatic and terrestrial landscape features, the proposed program allows us to design a statistically sound monitoring effort. Rather than attempt to monitor all areas, our system allows us to break the landscape into units which can be sub-sampled. This should make monitoring more efficient by reducing the number of locations which must be surveyed. As we improve our physical landscape model, we hope to be able to reduce the need for actual surveying or reduce the level of detail required to "read" a unit such as a stream segment.

2. By designing from the start, a multi scaled stratified classification and monitoring system, we will be able to provide information at a local level as desired and needed for some resource managers and management activities, and at a more regional or state wide level as needed for other management purposes. Since we are designing a system in which we have an understanding of the physical processes which are occurring at and between, classification units, the information gathered at a local

scale, for example regarding stream segments, will allow us to better understand regional or statewide processes occurring in units such as watersheds or ecoregions. Similarly, information collected about ecoregions, such as geological or hydrological data, will allow us to better interpret the characteristics of stream segments in and between ecoregions.

This approach is currently being evaluated and recommended by a number of researchers, however, the TFW monitoring and research program is the first opportunity to apply these concepts to a major monitoring program.

3. By using TFW monitoring data to refine our landscape model, we believe we will greatly improve our ability to interpret monitoring results and also determine how to extrapolate information between units. The classification system accounts for most of the major factors which influence habitat characteristics. By segregating the landscape into relatively homogeneous units, the monitoring system will "control" for many natural sources of variability. We believe this will enable TFW managers to interpret monitoring information much more accurately than has been possible in the past and more clearly describe the cause-effect relationship between forest practices and fish/wildlife habitat and water quality.

4. The landscape model, or classification system, identifies key variables which characterize the units. For example, variables which define ecoregions are climate, vegetation, and geology. Channel units are identified by gradient and channel form which are determined by local geology and climate (as expressed as hydrologic characteristics). The variables become units to be monitored. In further characterizing channel units, we identify key physical components such as channel width, depth, channel units (pools, riffles, etc..), flow, sediment, and obstructions (LOD, boulders, etc..). Each of these variables is related to the variables which characterize larger units. They also form basic features of habitat which effect biological productivity. Thus, the classification system guides us to the identification of many key variables which are natural, can be affected by management, and can affect biological resources. These variables become the "core" measurements taken statewide to characterize landscape units. This provides a consistent set of measurements which will be taken statewide, allowing comparison of different regions of the state.

   It is recognized that there are further variables or measurements which may influence local biological communities. In some areas it may be determined or believed that fine sediment is a controlling factor. In another it may be suspected that channel migration is playing a significant role. Measurements focusing on these variables will be defined as optional variables. These variables can be related to core variables, however it will not be possible, or desirable, to measure these variables at every location. The measurement methods can however be made which allows interpretation in terms of core variables.

5. By identifying consistent core and optional variables, biological research and monitoring can be conducted relative to these variables.

6. These variables are features which we can relate back to the manager and which we will be able to predict and design the effects of management strategies.

7. The combination of monitoring data, stream classification, a stream/landscape model, and research will allow the development of predictive tools needed by the manager to anticipate management effects.

STRATEGY

The Ambient Monitoring Steering Committee has identified a recommended strategy for initiating and implementing the TFW monitoring program. For purposes of this paper, we separate the monitoring and classification portions of the project and further identify short term (one to two years) and long term program elements.

It should be recognized that this strategy is subject to change based on the experience and further consideration by TFW Cooperators. Any changes in the future should consider the integrity of the program and data collected.

Classification

Short term

1. Formalize classification system based on input from Ambient Monitoring Steering Committee, CMER and other TFW Cooperators, and specialists.

2. Test classification using existing data as available and relevant.

3. Utilize classification to guide monitoring efforts.

Long term

1. Test classification based on TFW monitoring data.

2. Modify as needed.

3. Utilize classification to interpret monitoring data, integrate research and monitoring results, and develop predictive, site-specific tools.

4. Integrate classification into GIS and other resource management tools which are accessible and useable by resource managers.

5. Use classification concepts to adapt monitoring strategy.

Monitoring

Short term

1. Identify variables to be monitored through consultation with TFW Cooperators.

2. Identify methods by which variables are measured.

3. Identify sampling strategy

4. Begin field data collection in order to test methods and establish baseline record.
5. Use monitoring data to test/adapt classification system.
6. Coordinate with TFW research program to ensure compatibility.

Long term

1. Adapt 1-3 above as needed and indicated through experience.
2. Continue to monitor locations in order to establish resource trends.
3. Integrate data into GIS and other resource management tools to allow access and use by managers.
4. Integrate with research program to develop predictive and other resource management tools.

The classification and monitoring sections of this plan include greater detail and specific actions proposed for implementation of these general strategies.

STREAM CLASSIFICATION PROGRAM

INTRODUCTION

Rationale for classification

Natural environments and the ecosystems contained within them are complex and varied. Ecosystems are composed of diverse assemblages of species, with a wide range of life history types embedded in complex environments that exist at many spatial and temporal scales. Habitats and their biological communities change daily, seasonally, and annually, particularly in stream systems. Habitats are often distributed heterogeneously in space, and the productivity of any habitat depends on what other kinds of habitats lie nearby as well as the internal character of the habitat itself (Frissell and Liss 1986). Land management activities influence habitats in complex, subtle, and often important ways. To study, understand, and ultimately predict the effects of these land management activities, whether singly or in combination, on forest resources, some degree of environmental complexity must be reduced by modelling the environment according to simple principles of organization. Classification is one means by which we can do this.

The complexity in nature is not completely random or chaotic. Certain patterns occur on the landscape which produce certain other patterns in the habitats and communities that arise within them. These patterns occur at a number of spatial scales, and can be used through a classification system that characterizes these patterns, to better design research and monitoring programs and to interpret and apply results. Our purpose in developing a land-aquatic classification system within the TFW program is to identify and characterize useful patterns at a number of spatial scales that will be useful in stratifying and thereby reducing system variability.

By providing a framework to organize resource information, a classification is the necessary basis of any resource inventory. It can also be much more than a simple empirical tool for use in describing stream systems. Classification can also form a perspective from which one can understand what otherwise seems disordered or complicated, and can serve as a conceptual springboard for development of models describing system function and form. Thus, a classification is also an important first step in the understanding and study of the complex physical and biological systems of forest landscapes (Frissell and Liss 1986).

A classification should provide descriptions of landscape features according to their physical characteristics and should provide a framework for understanding and predicting habitat changes in response to land use practices. Therefore, terrestrial and aquatic classification systems will be useful for TFW planning, management and research.

Because systems are dynamic, a useful classification system must account for the potential states and performances of stream or terrestrial classes, not simply their present conditions (Warren 1979, McCullough 1987, Frissell and others 1986). As such, a classification should be derived in view of a system's potential capacity, and the capacity of its surrounding environment. Together these will determine the range of possible states that can be expected (Warren 1979).

The form a classification system takes depends not only on the nature of the objects being classified, but also on the theoretical perspective or assumptions, and on the objectives and perceived use of the system. TFW is concerned with multiple physical and biological resources including forests, fish and wildlife, and water quality or quantity. Ecosystems associated with each resource are described and understood differently, but each can share a common approach to their understanding through classification: A given physical environment will produce certain habitats that will, in turn, support certain biologic communities.

Many resources in a number of terrestrial and aquatic environments are influenced by forest management activities. It is therefore important to recognize and define all physically discrete, identifiable units in the landscape (Figure 1). Aquatic systems are extremely varied and range from flowing streams to lakes and wetlands. Forest management may affect each of these, although streams are by far the aquatic environments most commonly influenced directly or indirectly by forest practices. Terrestrial landscapes are also diverse. TFW landscape classification must provide descriptions of all important features.

Structure of the TFW classification system

There are many ways to approach classification. Classifications can range from relatively simple tools that are easy to use (although not necessarily simple to develop) to technologically complex methods.

A simple approach views classification as a means of identifying distinctive, mappable aquatic and terrestrial types. An understanding of how these types function is achieved after classification (or recognition of the type) through specific research or monitoring programs. Using the classification for management purposes requires mapping types across the landscape which demands recognition of boundaries or zones of rapid change along spatial gradients. Therefore, the classification, the technical tools to interpret and utilize it, and the map of types in the landscape are separate and independent elements.

An example of such a classification used widely in land management is soil classification. Vegetative productivity or other important forest responses are studied following soil typing. This knowledge can then be applied towards land management on broad areas by using soil surveys that yield easily interpretable maps of soil units. These maps can be used directly or added to geographic information systems (GIS) as an attribute overlay making them broadly available to a wide range of managers. The relative simplicity of soil mapping is balanced by the relatively low power of interpretation it provides. As with any classification system, interpretive power depends on the extent of backup research linking important characteristics to types and on the resolution and care used during surveys.

Another approach to classification derives from applied computer technologies. With the aid of computers, it is possible to compile large volumes of spatially defined data and to use complex statistical procedures to perform analysis of spatial aggregates (McCullough 1986). This sort of landscape interpretive technique may be more characterization than classification (Mosley 1987). Landscape characteristics may be coupled with computer models to build fairly powerful models for predicting system condition. In this sort of scheme, the landscape analysis, the technical interpretive tools, and the resource inventory are all combined into one system. This kind of tool could be powerful but it is also extremely data and technology intensive.

For the resources considered by TFW, we have insufficient resource information to allow development of a complex classification in the near term. While this may ultimately be desirable and feasible given some of the currently funded TFW projects, it is likely to take a number of years to develop. Furthermore, there is a need to constrain the number of identifiable types and to identify them in the near term so that we can orient research and monitoring projects to them. Therefore, for TFW purposes we will take a simple approach to classification.

The classification is seen as a geographic framework for organizing ecosystem resource information. The classification will identify appropriate mapping units. The ability to interpret and use mapped data will be developed independently of the classification, but tied to it. Methods to survey and map types will be determined.

TFW Application of AMSC Classification Method

The practical applications of a classification system are many. Landscape classification will be useful for development and application of monitoring and research results from TFW or other research programs. Classification units can provide a useful stratification for sampling design and will allow results from intensive studies of ecosystems or forest management practices to be extrapolated to similar terrestrial or aquatic types throughout the state. The classification units may serve as a useful template for comparing similarities and differences in ecological/environmental systems. The distribution and relative frequency of land and stream types throughout the state may also help in developing research and monitoring priorities.

Using classification to spatially organize the conduct of research and monitoring projects will help TFW managers to more effectively apply the results of such projects. The value and use of classification differs for each TFW management group:

Managers: Managers are responsible ultimately for achievement of TFW management objectives through adherence to forest practice regulations or through whatever alternative plans result in meeting objectives. Presumably the more resource information and predictive tools that managers have, the greater is their confidence that resource management objectives can be met using either regulations or site-specific prescriptions recommended in alternative plans.

A classification provides a means of organizing resource information and creating a foundation for understanding responses of natural systems to management so that managers can select practices appropriate to the site. One of the primary goals of classification is to provide a means to predict the biological or physical response of units to management prescriptions based on experience with a few similar units. These units can therefore provide the basis for the application of specific land management prescriptions or forest practice regulations. Land and stream types are important components of resource inventories.

Regulators: The classification provides a geographic orientation for characterizing "baseline" conditions and provides a basis for the spatial sampling scheme for a monitoring network. It can also help develop the rationale for measuring parameters that are likely to vary with forest management.

Policy-makers: With a better understanding of natural variability and monitoring of changes with management practices, policy makers may ultimately be able to establish water quality standards and forest practices that are in tune with regional patterns of tolerances and resiliences to forest management effects.

Classification Goals

In order to fulfill these functions, the classification schemes must consist of mappable units that are of sufficient size to be reasonably utilized in forest management, but small and discrete enough to provide useful stratification of resource differences. The general characteristics of units should differ sufficiently to distinguish them. Also, biological communities associated with specific units should demonstrate quantifiable similarities and patterns in time. Finally, unit characteristics (but not the differentiating characteristics) must be shown to vary in response to environmental changes induced by forest management or naturally occurring events.

Terrestrial and aquatic classification schemes will be constructed based on patterns in the more static aspects of these system conditions so that mapping units are more or less permanent. The permanent components of the classification is the framework upon which the dynamic properties of the systems can be accounted for. This aspect of classification is crucial for utility in monitoring and management.

Overall Classification Strategy

Aquatic and terrestrial systems, though inextricably linked, are sufficiently distinct that their classification schemes may be developed more or less independently. The ties between these two systems will be carefully examined to ensure the two classification systems will be relatable at various spatial scales.

The Ambient Monitoring Steering committee will review existing methodologies for describing a variety of aquatic habitats. Where appropriate classification schemes exist, the AMSC will adopt one for TFW applications. No single integrative, systematic framework presently exists for understanding the considerable natural variability within and among stream systems (Frissell and Liss 1986). Because of the important influence of forest management on streams,developing such a system will be a primary focus of the AMSC classification research efforts. This will require monitoring and research activities described elsewhere in this workplan. Furthermore, distinctive aspects of aquatic systems such as lakes, wetlands, and beaver ponds will be specially addressed within our classification.

Many terrestrial classification schemes exist and may prove suitable for use in TFW. The terrestrial classification will be developed jointly by the Ambient Monitoring Steering Committee and the Wildlife Steering Committee. Initial work will consiste of a literature review and analysis of terrestrial habitat classifications. This review is in progress and is being performed in conjunction with the more general review of wildlife use of manager forests (CMER project 17). As a result of this analysis, the Wildlfie Steering Committee will propose a suitable terrestrial classification scheme, and if necessary, will modify it to ensure its compatibility with the aquatic component of the overall classfication system.

CLASSIFICATION PROGRAM ELEMENTS

Development of the stream classification methodology and its use in TFW applications requires consideration of two major topic areas, each with distinct pathways of short and longer term steps to achieve specific goals. We will consider these as major program elements and will provide rationale and strategy for each one. We will identify the objectives of each of these program elements and the steps to achieve those objectives over the next several years of the TFW program.

The first stream classification program element (Stream Classification) focuses on devising the structure and methods of a classification scheme that will be widely applicable in Washington streams. The goal of this program is to develop identification methods and techniques for mapping stream types and to implement sampling programs for characterizing streams throughout the state.

The second program element seeks to develop a means of assessing stream characteristics that are responsive to changes related to natural or forest management watershed disturbance by stream types identified in the classification system (Stream Response Assessment). This program will allow long-term monitoring programs to assess resource baseline and trends by identifying key variables to measure and expected relationships with watershed and management characteristics.

Proposed Stream Classification Method

Rationale

Physical conditions of rivers such as velocity, depth, width, substrate, temperature, and debris loading change from headwaters to mouth. From a broad perspective, channel changes are relatively continuous along the system as drainage area continuously increases and the mainstem gradient decreases. Biological communities reflect these changes owing to their inherent tendencies to structurally adapt and conform to the most probable state of the physical system. Downstream trends in the physical stream system lead to systematic changes in species composition and abundance throughout a river system (The River Continuum Concept: Vannote et al. 1980).

Although broad systematic changes in river systems are readily apparent, stream conditions can vary longitudinally. Sharply defined junctures between discretely different stream conditions are often striking. Streams have been described and classified at several spatial scales (Table 1) with a number of classification methods. Frissell et al. (1986) provide a broad conceptual approach to stream classification that attempts to organize these variaous approaches into a hierarchical classification of increasingly finer spatial scales. When each of the individual methods for each spatial scale and the overall hierarchical framework was examined in detail, we found that none of the existing methods in and of itself was shown to satisfy the objectives that we have asked of a stream classification method. Classifications at each spatial scale failed to account for all the important attributes that distinguish streams, and the hierarchical organization includes some levels thought to be impractical at this stage in the context of the entire TFW research program. However, the repeated recognition of stream patterns in earlier works suggests a successful classification system is feasible. Rather than develop an entirely new approach to classification, however, our proposed model builds on the work of many others and

incorporates these ideas into a framework that we believe will lend itself to field verification.

To develop a classification, we begin by mapping or typing units that account for important attributes of the landscape that should directly influence the character of streams. Types that are easily observable and mapped are most desirable. Some physical aspects of landscape features are static over long timeframes and this makes them particularly amenable to incorporation into a classification system because boundaries of units will not vary except on geologic timeframes. It is highly desirable from a mapping perspective to identify diagnostic features of classification types and boundaries between units to vary with time.

The reason for watershed/stream classification is to characterize regional differences and similarities in streams recognizing that the relationship between areal phenomena and streams varies with watershed size and geographic region (Hughes and Omernik 1981). Broad consideration of streams and erosion processes suggests that factors generally important in stream formation include geology, climate (hydrologic regime), vegetation types, watershed size, and valley characteristics (Table 2). Our approach to classification is to identify existing methods for characterizing spatial pattern in these factors. To keep the classification as simple as possible, we only consider levels that provide stratification of these attributes and are permanent mapping features.

Other important smaller scale features of streams are recognized as being very dynamic over time. While it is necessary to account for these dynamic properties of streams because they are important to ecosystems, they are less useful in the construction of the system and are not amenable to mapping. We will develop an approach to characterizing the dynamic characteristics of streams in relation to the classification in the second AMSC program element (Stream Response Assessment). This will allow us to link monitoring and classification in forest management considerations.

Classification Method

Several existing classification methods should be suitable for characterizing the variables described above (Table 2). We feel that it is best to aim our efforts at the most appropriate spatial scale that will both satisfy the classification objectives and lend itself to field application. Appropriate spatial scales for TFW are those that (1) match the scale of use of habitat by fish in their life stages and over the cou4rse of its freshwater development and (2) match the scale at which various management treatments and regulations can be applied. In the context of these scales we must assess water quality, channel morphology, sediment and associated hydrological regimes.

Broad patterns in climate and natural vegetation have been described with mapping units termed ecoregions (Bailey 1976; Omernik and Gallant 1986). Ecoregions are broad geographic areas of similar climate and vegetation. There are 6 ecoregions in Washington according the EPA ecoregion designation. If major geologic types are included, however, there are as many as 15 distinct subregional zones. A general map of proposed ecoregions of Washington merging the EPA ecoregions with dominant lithologic zonation is shown in Figure 2. This map is preliminary and may be revised as classification studies progress. Final ecoregion demarcations will include only areas sufficiently distinct in stream types to warrant their uniqueness.

Watershed size has been indexed in a number of ways. Techniques vary from considering drainage area (a continual scale), to stream ordering (discrete, and easy to identify similar types). While watersheds are an extremely useful and important planning or study unit, we prefer to avoid basins or subbasins as a classification type because the size scale is continual and because this approach does not lend itself to identifying similar types across broad geographic areas. If streams reflect their watersheds and if many watersheds have similar characteristics, then it should be possible to group watershed/stream systems in a number of useful but broader categories that cover broader regions (Hughes and Omernik 1981).

Stream order is a useful and easy means of communicating the relative sizes of streams within drainage basins. It is a quantification of the linear properties of drainage networks. Strahler's method (1957) designates unbranched tributaries as first order, streams receiving 2 or more first order streams as second order, streams receiving 2 or more second order streams as third order, and so forth. Stream orders have proven useful for organizing stream processes and understanding their relationships to biological communities (Platts, 1979; Beecher et al. 1988; and many others) because there tend to be correlations between stream area and even relief geomorphic characteristics in similar regions. Hughes and Omernik (1981) caution, however, that stream order is not universally applicable for comparing stream sizes, watershed areas, or watershed relief, or the biotic characteristics of streams because these correlations vary significantly between regions. Some of the problems associated with using stream orders stems from the varying methods of designating stream order. They suggest using indices of flow as an alternative means of indexing stream size.

Another approach to characterizing streams that relates to stream size is the geohydraulic zone. Geohydraulic zones represent broad changes in river and stream characteristics within a large basin as elevation declines with distance from watershed divide (Bauer). This system is more dependent on stream gradient than stream size. Broadly recognized geomorphic stream or water types such as step-pool (steep), straight (moderately steep), meandering (gentle) and estuaries (sea level) are illustrated in Figure 3. These riverine zones occur in virtually all basins and characteristic longitudinal and cross-sectional stream morphologies have been associated with them (Leopold et al. 1964). Zones have primarily been differentiated in classification systems based on overall gradient and particle sizes, but within any geographic area geohydraulic zones tend to be representative of stream size. The combination of stream order, geohydraulic zone or discharge characteristics might effectively incorporate stream size for a given ecoregion in a manner than neither can do separately.

The influence of valley conditions on stream channels has been characterized in several classifications that describe relatively homogeneous lengths of stream contained within similar geomorphic settings (Rosgen, and others that vary his method Cupp, Alaska, etc.). Stream segments are associated with valley gradient and are demarcated by contacts between geologic rock types of variable resistance, or by abrupt change in valley conditions or geomorphic landforms (Figure 4). A segment is a unique part of a stream with beginning and end-points corresponding to stream coordinates. As such, they are the basic stream mapping unit.

We define a segment as a stream section with uniform valley gradient and with minimum length of 20-30 channel widths ranging to 1000's of meters. Average segment length (distance between slope breaks) probably increases with watershed and stream size. (The term segment should not be confused with the term "reach", which we define as a

stream section of arbitrary length selected for the purpose of stream sampling.) Segments are large enough units that they can be mapped from topographic, geologic and climatic maps. Onsite surveys may be necessary to verify segment type, but only infrequently.

We view watersheds as a series of segments joined at discernible changes in gradient at map scales of 1:24,000 (Figure 5). Where slope change is a smooth curve, the breaks may be more arbitrary, and knowledge of fish zonation could be superimposed to define unit boundaries. Because segment slope is controlled by factors extrinsic to the stream itself, stream segments provide a useful orientation for stream classification in that gradient is indifferent to disturbance of stream processes occurring over centuries or longer. From a conceptual standpoint, segments are seen as discrete lengths of stream, with characteristic spatio-temporal erosional and depositional profiles. There are a finite number of segment types that exist based on a limited number of classes delimited by slope categories that should be useful in identifying dominant physical environments. For example, Rosgen (1985) identified 25 segment types that characteristically occur in mountainous terrain of the western United States. A modification of Rosgen's method developed for use in fish-bearing streams of the Gifford Pinchot National Forest in Washington identifies 9 segment types (Cupp, in press).

We hypothesize that the occurrence of segment types may vary within watersheds according to stream size and between watersheds regionally according to differences in geology and climate. For example, steep segments will not have channels that resemble low-gradient segments; segments in large streams will not be the same as those in small streams; and segments found in streams in sandstone geologies may differ from those found in granite terrain.

General tasks here will be to identify units within each classification level using a set of diagnostic variables (Table 3). An important consideration in developing diagnostic tools for distinguishing segments is to <u>not</u> include variables that may vary with disturbance. If this occurs, the segment type and therefore mapping units will vary with disturbance.

We have targeted segments as the primary mapping unit of our classification, and we envision that if properly identified, this level will prove to be the most useful to land managers. Segments constitute mappable units that may be easily recognized by forest and habitat managers. Furthermore, this is the finest spatial scale stream class for which the occurrence of units is dependent on geomorphological class at the watershed scale, and the stream classes can be recognized independently of watershed class. In addition, forest management practices occur at geographic scales with effects that can be examined at the segment spatial scale. Managed units provide cumulative effects at a basin scale, but we hypothesize that the effects on streams may be expressed differently from segment to segment downstream in the basin.

Our approach to stream classification largely focuses on describing segments, understanding their distribution relative to watershed features, their probable condition under baseline and disturbed regimes, and their potential for biological productivity under a variety of conditions.

<u>Goals</u>

To develop the structure of the stream classification scheme including methods for identifying units in each class, mapping techniques, and analysis of the occurrence of stream types within the state.

Strategy

To map and characterize stream types we first need to identify all appropriate stream types found in Washington. We will use existing classification methods where possible (ecoregions, segments, etc.) but will refine and modify systems as needed. We must develop methods and diagnostic characteristics to identify units within classes. These diagnostic techniques must be field tested with a combination of field surveys and studies to demonstrate that their are quantifiable differences between units. Once a classification methodology is fully developed, we will need to survey a number of locations in the state to determine the spatial distribution of stream types and to characterize regional differences in baseline conditions.

TFW Application

As we have framed our approach to stream classification, the stream segment represents the unit of mapping. Identification and mapping of segment types can be performed from topographic and geologic maps of the state. As envisioned in the classification approach, identification of segment types does not require stream surveys. To apply widely in the state, surveys or maps of streams in the state could be performed. If this information were available on a geographic information system the job could be performed relatively easily for forestlands throughout the state. Techniques for stream typing can also be applied in local areas from topographic maps for identifying monitoring or research sites.

Stream types should be considered a planning unit much like the stream types currently used in the state, although they will be more fine-tuned to watershed and climatic factors than the current method. In particular, they will be far more amenable to extending research results to similar stream types.

Some information regarding probable stream condition and response to forest management is intrinsic to the segment and best management practices could be prescribed specifically to segment types. This may be feasible particularly because of the ability to apply research results more appropriately to similar stream types. For the same reason, and because segments are relatively large scale features, they may also be useful in basin planning. In this context they may provide a mapping of general areas of high or low sensitivity to particular management practices. In addition, segments provide a conceptual basis for system modelling of cumulative effects and could be the centerpiece for constructing interpretations.

Because segments are identified from maps and not field surveys, they do not possess information that provides a reading of current stream conditions. Application of site-specific prescriptions and prediction of management effects will require local stream data and relationships described in the second AMSC program element.

Program Steps

General steps suggested for each program elements are listed, although not necessarily in a sequential order. Individual projects will be developed to gather the information identified in these steps. Many of these projects will be conducted concurrently within the AMSC program. Each step will be developed in more detail with study plans for specific projects. Existing projects or proposals have been identified relative to the appropriate step. Some of the projects will be carried out by TFW participants, others will be fully or cooperatively funded studies from TFW Ambient Monitoring Committee funds.

A) Identify the appropriate classification levels and units within them. Develop diagnostic variables that can be used to identify units.

    1) A Proposal to Fully Develop Stream Classification in Washington (E. Cupp, Univ. of Washington)

B) Provide methods for stream typing and training to TFW participants. Initial efforts will include developing field or mapping methods. The AMSC will also consider developing methods for stream typing throughout the state that can be applied with a GIS system.

1) Classification Methodology and Training (E. Cupp, Univ. of Washington)

C) Field verify that units can be reliably distinguished from one another and that units account for differences in watershed input factors or biological productivity.

1) A proposal to test the stream classification system--Stillaguamish River) (T. Beechie, Univ. of Washington)

2) Interpreting results of stream surveys in southwest Washington (E. Cupp, Univ. of Washington)

D) Conduct surveys throughout the state to determine regional and watershed variations within ecoregion and stream types.

1) Statistical sampling design (L. Conquest, Univ. of Washington)

2) Statewide monitoring program (NWIFC)

Stream Response Assessment With Classification

Rationale

The stream classification scheme outlined in the preceding section provides a mapping plan for stream types. The stream classes that we have identified occur broadly in watersheds throughout the Pacific Northwest region and are formed by large scale physical processes that are for the most part independent of changes in erosion or hydrology caused by watershed disturbance. Stream types are expected to have similar characteristics under equivalent watershed conditions and to respond similarly to changes in sediment and hydrologic input to a watershed.

The approach we have presented provides a relatively simple mapping method in that it identifies segments from topographic and geologic maps. Segments are stream types determined by valley conditions and as such their location tends to remain constant on timeframes important to forest management considerations. Segment types represent the "potential" of the stream and provide constraints on the probable form that the channel can have within it.

When the classification is applied from such remote data, however, it simply suggests probable stream conditions. Units mapped in this fashion contain no information about present stream states, although most probable states might be inferred, given knowledge of watershed condition and experience with the segment type. This is important, because at finer spatial scales the structure of channels can be highly variable in time responding to changes in the rates of important processes that determine stream morphology including sediment and flow regimes and the frequency of channel obstructions (Sullivan et al. 1987). This spatial-temporal variability is an inherent characteristic of a segment type defined by more stable features.

Geology and climate may strongly influence stream channels by determining the type and input rate of sediment as well as quantity and timing of flows available to transport the

sediment. Forest management activities can also affect each of the input variables directly or indirectly with resultant effects on stream channels. Accelerated rates of sediment input, removal of channel obstructions (large organic debris) and altered flow regimes have been identified as significant effects of forest management.

The current "state" of a segment may vary over the range of potential channel conditions characteristic of each type depending on current and historic interplay of the input variables reflecting climatic variability and the history of natural or land-use disturbance influencing each segment (Figure 6). Therefore, the channel characteristics of a segment can also vary over time but the potential of each segment has finite boundaries. Within a region it is feasible that, at any one time, two segments of the same type may be at opposite ends of the scale of potential for that particular segment type.

By classifying streams we can identify the general stream properties and responses associated with stream types that occur widely within broad geographic areas. However, an evaluation of stream conditions and probable response to watershed disturbance can only be done by considering each local site within the context of the basin in which it is located. Each basin has unique combinations of geologic and climatic conditions, as well as a history of storms and past disturbance.

A challenge to stream classification lies in the ability to recognize segments that are variously expressed under natural and managed streamside and watershed conditions. Segments may in fact represent the most variable of the classification units and could prove difficult to categorize without understanding watershed erosion processes and rates. Variability occurs both spatially (segments integrate sediment and flow characteristics of other parts of the watershed upstream as well as variable conditions within them) and temporally (a piece of large organic debris has a finite life as a channel obstruction, and there is a steady turnover rate of debris and channel morphology within segments).

Accounting for the dynamic aspect of stream channels presents a difficult problem in stream classification and is the primary reason why we do not include a smaller scale classification level such as riffles and pools in our scheme. Finding a way to characterize the dynamic characteristics of streams within the classification framework will be important because many of the most temporally variant characteristics of streams are also the most important features that influence aquatic biota.

Using stream classification to predict natural and management-induced responses to variation in watershed erosion, sedimentation or hydrologic processes or for habitat features requires stream survey and an understanding of the influence of sedimentation and erosion rates on stream conditions. A major task in refinement of this stream classification is therefore to identify and quantify the relationships between channel characteristics and the volume and quality of sediment and obstructions and to flow regime by stream type.

To assess the success of TFW management practices in protecting aquatic resources, the monitoring program must track key variables through time that are associated with sediment and hydrologic regime and that are responsive to changes in terrestrial units near segments and to cumulative changes throughout the watershed. A successful monitoring program will require an assessment of current channel conditions by surveying key variables expected to change with disturbance. Since each segment is a product of unique watershed conditions and history of disturbance, it is important that we be able to "read" stream survey data to interpret the current channel conditions relative to each of these factors.

Stream morphologic indices constitute the basis of most stream classifications. Without consideration of stream formative processes, however, they do not allow linkage of segment morphology with watershed processes and how forest management is likely to alter them. The stream types that we recognize with stream classification reflect the interaction of geologic, hydrologic and hydraulic processes in different watershed environments. To capture the essence of these important process interactions, we intend to develop our classification system within a theoretical framework that is based on principles of physical processes. Although a landscape-scale sediment transport theory has not yet been developed for stream classification, there is sufficient physical understanding of the most basic and pertinent stream-forming processes to allow us to proceed with classification.

We believe such an approach can be used to develop both a stream classification method and an assessment of sub-basin and basin cumulative effects associated with management-induced changes in watershed process rates. To develop the interpretive tools that link stream response to forest management to the classification, we must start with a conceptual framework for describing streams and identifying variables that can be used to assess the state of the stream system. An understanding of stream processes should enable us to refine our list of variables and to develop hypotheses of probable trends in important stream characteristics under natural and management disturbance regimes. This conceptual framework must suggest a means to characterize the conditions within any given segment, as well as a means of relating each segment to the watershed in which it is located (cumulative effects). This approach should also enable us to develop a method that is useful for assessing biotic conditions of streams. Further research into processes can help to refine our scheme and test its usefulness.

The following section provides details on the foundation of our classification theory--physical processes of streams--and lays the groundwork for research and the integration of monitoring and classification aspects of our TFW task. The segment is considered the fundamental stream mapping unit and our conceptual stream model and biologic interpretation will be developed relative to them.

General Stream Model and Classification

Simply described, patterns in channel and valley morphology result from the interaction of water, the range of sediment particle sizes it moves, and the landscape through which it carries these sediments. These factors are a reflection of stream power, that is, the availability of energy to do work. Stream power was defined by Bagnold (1966) as the product of the velocity, energy slope, and specific gravity of water. A primary factor influencing the erosive capacity of streams is energy slope which is generally assumed to approximate change in water surface or bed elevation over long distances. Beschta and Platts (1986) discuss the importance of the stream power concept in providing a basis for understanding the erosive capability of flowing water in open channel systems and how streams with various slopes, widths and depths, and roughness characteristics produce different erosive characteristics. Erosion and subsequent deposition will, in turn, lead to the formation of the channel patterns we recognize. Because of this interaction between erosive force, particle characteristics, and energy slope, we expect stream gradient to be a primary variable that distinguishes stream units. (Channel gradient distinguishes units at a number of spatial scales including geohydraulic zones, segments and channel units according to Bauer , Rosgen 1985, and Sullivan 1986 respectively.)

Input variables. The primary environmental factors determining channel condition within a segment at a point in time are sediment regime (amount and particle size), flow regime (amount and timing), and channel obstructions (substrate, LOD, confinement; Sullivan et al. 1987). Consistent with general systems theory (Orsborn and Anderson 1986), these will be referred to as "input" variables in that they are factors that are in large part outside the control of the stream flowing within a segment (figure 6).

We envision that a segment would have different characteristics depending on sediment loading, hydrologic conditions and obstruction frequency. Interpretations of channel responses for segments of a given class would necessitate determining the current position on a sediment loading continuum from "sediment poor" to "sediment rich." Segment class can be determined using the variables that are a proxy for segment potential. We expect that channels of a given class will respond to an absolute increase in sediment input in a manner related to its present position on the "loading continuum." Proximity to a loading threshold might determine the probability of a new sediment pulse producing a major change in channel unit distribution or other channel characteristics.

Response variables. To develop the relationship between input variables and stream channels, we must identify variables to be measured that respond to changes in the input factors. Response variables are defined as characteristics that change in relation to the input variables. For example, several variables that are expected to respond according to the status of the input variables (individual or combined) are channel unit distribution and channel pattern, and bed material size (Table 4). A complete list of appropriate response variables relative to sedimentation and hydrology processes needs to be identified based on a consideration of physical stream processes.

Environmental indices. The current level of input factors could be determined by indices of response variables that reflect the prevailing sediment rates, flow regime or obstruction characteristics. Such environmental indices may be one or more response variables that indicate the general level of an input variable. Since each of these rates varies in time, the response variables should have some probability functions associated with them.

The current state of a segment has a strong influence on probable response to management activity and is an important starting point for understanding observed trends or predicting probable changes with a management activity. For prediction purposes, we expect a stream that transports relatively low sediment volume (sediment poor) to respond differently to an influx of sediment than a stream that is already sediment rich. In many situations we may be looking for thresholds where above some value significant change is observed.

In our classification, segments could be characterized by high or low sediment regimes, flow, obstructions and so on based on the environmental indices (Figure 7). We expect that natural or baseline rates of the input variables would vary between regions reflecting geology and climate. Characterizing regional differences in streams with the monitoring program would involve determining the conditions of input factors relative to broadscale regional or watershed processes (ecoregions and streamsize) and determining average stream conditions within stream types. This approach of interpreting channel characteristics based on rates of input variables replaces the approach of comparing streams to an assumed "baseline" condition based on management history. It should lead to better tools to predict direction and magnitude of change in response to local and upstream changes.

Effects of management activities may be understood by determining the cause and effect relationships between specific activities and the indices of input variables. For example, the relationship between LOD-produced obstructions in channels and the number of trees in the riparian zone can eventually be translated to an index of habitat availability through the influence of LOD on channel unit distribution.

Cumulative effects.

Changes in stream and erosion rate occurring in one part of a watershed can influence other parts of the watershed downstream. Many physical processes operate simultaneously within a stream system to deliver materials or energy such as water, sediment, woody debris, nutrients and heat from the surrounding landscape and atmosphere. All of these characteristics are influential in determining channel morphology and the suitability of a stream for fish habitat. These materials are either stored or transported downstream where they become important to fish. Watershed conditions dictate the rate of material transfer to the stream system, and changes in their input rates raise many of the concerns associated with forest management activities (Geppert et al. 1984; Reid et al. 1988).

Watersheds and the series of segments in a drainage system are linked systems through which materials, once introduced to the stream, are transferred from segment to segment or are stored in and released from segments episodically as a function of water flow regimes and retention capacities of segments (Figure 8). We view material transfer within stream systems as occurring from segment to segment. The transport rate of each of these materials (e.g. water, sediment, nutrients, and woody debris) between segments and the mechanics of storage may vary.

Material introduced at any location within a basin is transported from segment to segment at a rate representing the opposing forces of streamflow transport and retention capability of the segments. Coupling the rate of input with transport and storage within a stream system will be critical elements of relating stream characteristics with basin-wide erosion processes. For example, sediment budgets characterizing the delivery of sediment to streams need to be coupled with transport rates and indices of channel response (Dietrich et al. 1982). Adjustment of channels to material moving through will reflect amounts introduced upstream as well as local site conditions. Basinwide or cumulative effects interpretations will come from understanding the rate of transport through segments, as well as reading the channel and stream conditions for impact due to that material moving through.

In principle, each segment responds to material contributed by the entire basin upstream. In practical terms, however, there is probably some definable primary zone of influence upstream of a given segment that is demonstrably linked with the segment or series of segments and can account for the most short-term responses in channel morphology. Identifying this zone would be useful as a first approximation in linking management effects with stream conditions. Ultimately perhaps entire basin relationships can be understood and described with deterministic models.

Ecological Link to Stream Segments

To manage streams for biological productivity, we start from the assumption that production can in some way be related to the characteristic habitat conditions associated with the physical stream environment. Appropriate measures of fish productivity remain a

topic for debate, and may include smolt output from a basin, adult escapement, population levels at life history phases, species diversity, or even genetic diversity.

There is vast body of literature that demonstrates the intimate relationship between stream biota and the physical characteristics of rivers and streams. Flow, bed substrate, temperature and water chemistry characteristics are important in determining the suitability of streams for providing habitat for fishes and macroinvertebrates (Reiser and Bjornn 1979). These characteristics are in turn influenced by local climate, watershed, stream channel and riparian vegetation characteristics.

Relating aquatic biota to physical stream conditions has been done at a number of spatial scales in the Pacific Northwest region. Broad differences in the geographic distributions of fishes has been shown to relate to ecoregions (Whittier et al. 1988; Li and others, in press). Within watersheds, general patterns of species distribution and abundance have been shown to relate to stream order (Beecher et al. 1988) and general channel gradient (Gibbons et al. 1985). Relationships between stream order and ecologically significant variables (gradient, channel width and depth, and bed sediment character) and fish species present have been demonstrated in a number of other locations throughout the world. Although the reality of longitudinal variation in river character and ecology has been demonstrated in many studies, there is a view that transitions have the nature more of a continuum than of a series of distinctive zones or river types (Mosley 1987).

Segments are identified as moderately long stream lengths within channel or valley gradient classes indicating that habitat characteristics are likely to vary between them. Cupp (in press) demonstrated differences in fish species and abundance relative to segments in the Cascades mountains of Washington. However, Reeves and Everest (in press) found that the similar Rosgen segment classification method by itself did not provide a viable classification system for extrapolating relationships between biota and channel characteristics to similar stream types in the Coast range of Oregon. The applicability of segments as a useful typing method for differentiating aquatic biota may be determined by the extent to which smaller scale channel features to which aquatic communities are more directly oriented can be systematically characterized.

We feel that by including the analysis of stream channel response variable to highly variable watershed environmental factors may solve some of the problems identified by Reeves and Everest (in press) in using stream classification to predict aquatic productivity. Important physical habitat conditions such as channel unit distribution, bed substrate, flow characteristics and temperature are all likely to vary systematically with watershed conditions and rates of environmental input variables. Available habitat may be directly linked to segments, and segments may provide an index of available habitat.

Increasingly, channel units have been the focus of ecological interpretation of the habitat characteristics of streams (Bisson et al. 1982, and many others). Channel units differ in physical habitat conditions (Sullivan 1986) and species utilization (Bisson et al. 1982) making them useful for interpreting individual organism and population behavior. Although channel units are recognized as extremely important for understanding aquatic ecology, they are not included as a level in the stream classification because they are small and time consuming to map and because channel unit location can be variable from year to year. However, channel unit distribution is expected to demonstrate relationships to watershed conditions relative to stream segment type. For example, Gibbons et al (1985)

showed that channel units preferred by steelhead juveniles for rearing varied with stream zones explaining differences in productivity.

Accounting for fish habitat requirements through its life history requires a conceptualization of habitat at a variety of spatial scales (Table 1). In most cases, the level of understanding of potential productivity for units within each class is relative and largely descriptive. For example, recognition of geohydraulic zones is useful for determining species use of the basin for each life history phase, but without more detailed mapping cannot provide actual estimates of smolt output, only potential estimates.

Fish production is a function of the condition of fish habitat. Physical habitat distribution and composition must consider the structure and performances of the entire stream network. Segments are not independent systems but are strongly linked in series with upstream segments and watersheds. Fish production, being an outcome of a total drainage system, highlights the linkages in the downstream direction. That is, fish originating from one segment might rear in upstream and downstream segments on their way to the ocean.

Factors that influence what types of fish and many are produced in a stream segment can be grouped spatially: source and other upstream factors (influences on the delivery of material to each stream segment), on-site factors (habitat conditions within segments), and downstream factors (lakes, barriers, etc.). Some of these do not fit neatly into proposed hierarchies of classification. However, within watersheds these factors can be accounted for by accounting for stream segments relative to watershed position and assessing their condition as a function of watershed conditions.

Biological makeup of each segment must also be characterized and understood relative to the habitat conditions provided for each life history phase (summer rearing, overwintering, spawning etc.) for each species (resident, anadromous trout, salmon, etc.) (Figure 9). Interpretation of actual production of a watershed is dependent on the array of "potential" segments within a basin as well as barriers or other important large-scale features that will determine how many or what type of fish may be present (limiting factors analysis). Anadromous fish are highly mobile during their life in freshwater. The fisheries potential for the basin may be determined by the ability of individuals to find and utilize a series of stream segments providing appropriate habitat features such as flow characteristics, substrate, temperature, water chemistry, etc. for each life history phase. Production from the watershed over time is limited by the availability of the most scarce habitat during the freshwater life cycle. Actual production from the watershed can vary from the potential for any generation due to factors that influence escapement, climatic variability, and so forth.

To the extent that a segment relates to the potential for channel conditions, it also suggests the potential for habitat conditions. Determining the relationship between fish populations and stream environments remains a primary challenge to fisheries scientists. This has proven a difficult task because populations are subject to factors extrinsic to basins, multiple ecological factors operate simultaneously to determine usable stream habitat and there a number of species and age classes to determine habitat needs for.

Goals

Stream classification focuses on describing the general, relatively permanent features of a stream location. Materials that have long residence times such as LOD and sediment end

up being a part of the stream description in stream surveys. Materials that have short residence times such as flow volume, temperature, and nutrients, can be characterized by regime (conditions, volume, conc., etc. over time). A monitoring program may be necessary to characterize average and altered regimes of important habitat variables. One approach to determining the cumulative effects over time of various management activities on fish populations involves linking a model predicting fish standing crop from habitat variables to one predicting these same habitat variables from land management practices (Fausch et al. 1988).

Effective utilization of the stream classification scheme to relate watershed conditions and aquatic biota to forest management practices will require monitoring current and future trends of important physical characteristics of streams. The goal of this program element will be to identify appropriate response variables to monitor and to develop a sound understanding of these stream characteristics in relation to forest management by stream type.

Strategy

We will develop sound hypotheses of appropriate variables that are expected to be affected by land management practices (response variables) and their relationships to environmental input factors by carefully considering geomorphic theories regarding processes of erosion, sediment transport and hydrology. Relationships between various watershed conditions and response variables will then be determined in intensive studies. Streams will be monitored for response variables in various geographic settings with different watershed conditions, and in relation to specific forest management practices to determine the relationships of channel conditions to watershed characteristics. Channel characteristics indicative of watershed conditions will be evaluated with indices of loading levels. Intensive studies of channel response to different loading levels will eventually allow prediction of a channel's future conditions based on assessment of its current status and expected land use effects.

TFW Application

Identification of appropriate response variables and their expected relationship with environmental factor loading levels will determine the variables to be included in long-term monitoring programs assessing the effectiveness of forest practice regulations. Monitoring programs will determine the baseline conditions by region and effects of forest practices on stream channel characteristics.

These relationships will ultimately prove useful for developing site-specific management plans under the TFW alternative planning process. As envisioned with our stream classification program, site specific prescriptions must be developed based on current local stream conditions which can be assessed by stream surveys. The loading indices based on stream survey variables will provide an estimate of the overall physical and biologic condition of the site and probable direction and magnitude of change with management practices. Indices and site interpretations are linked to the site of interest with relationships developed for segments intensively studied in the research and monitoring program.

Program steps

A) Fully develop the theoretical hypothesis of stream conditions based on stream processes. Identify appropriate response variables and develop field methods for measuring them. Develop hypotheses of expected relationships.

   1) Think Tank of geomorphic and biologic experts to be held in May 1989.

   2) General study proposal for developing stream classification relationships (J. Orsborn, Washington State Univ.)

B) Determine the relationship between response variables and the input variables (flow regime, sediment, channel obstructions etc.).

C) Develop indices of one or more response variables that indicate current status of physical stream conditions.

D) Characterize response variable characteristics by segment type under natural and disturbed rates of input variables. Establish temporal variability of dynamic properties of streams.

   1) A Proposal to test the Stream Classification System (T. Beechie, Univ. of Washington)

E) Predict direction and magnitude of change in channel conditions onsite and downstream, and recovery rates from management activities (cumulative effects).

Summary of Classification Program

In this section of the workplan we have developed an approach to stream classification that will provide a relatively simple method for identifying unique stream types that can be applied throughout the diverse regions of Washington. The proposed classification scheme focuses on mapping units of a sufficiently broad spatial scale that they can be easily identified by foresters or habitat managers and that can be mapped from existing topographic and geologic maps for the most part. These stream types should be used as a basis of site identification for any field studies or monitoring efforts so that results of those studies can be extrapolated to similar types.

The general hypotheses of stream classification, ecologic and management interpretations presented in this workplan have been developed based on geomorphic and ecologic theory. This foundation may increase our chances of successfully achieving our goals, especially if the major environmental factors can be identified leading to reasonably simple descriptors of stream conditions. Our general approach incorporates the ideas of many and appears to be compatible with a number of classification systems already in use. While the ability to recognize and describe watershed pattern is well documented, the ability to interpret watersheds for fisheries or management effects remains largely theoretical. While our basis appears well thought out, it may not prove to be entirely correct. We will have to learn and adapt as we proceed.

Because of the broad spatial orientation of the mapping units, the classification is recognized as having fairly low resolution for predicting stream response to management

effects or biological populations. 'We have made an important step towards improving resolution of the system for relating to local site conditions by recognizing that streams at the riffle and pool scale are highly dynamic and responsive to the rates of input factors such as sediment and obstructions and flow characteristics. Our efforts to characterize the relationship between these environmental factors and channel characteristics (channel unit distribution, bed substrate, width, depth and bank stability and so on) should lead to key variables that can be measured at a given site and used as an index to "read" channels for the current conditions and ultimately predict the response of the system to future changes. Establishing a matrix of likely channel characteristics under various levels of input factors should also allow an improved description of habitat conditions for aquatic biota.

The response variables will form the basis for a long-term monitoring program to be described in the following section of this workplan. The monitoring program will document baseline conditions of response variables based on regional characteristic rates and conditions of the input factors (i.e., geology, climate and natural vegetation types, and stream size) by stream type. The response variables will also be monitored through time and related to changes in the input factors as a result of natural (large storms) or land use disturbance (road construction, etc.) so that the effectiveness of forest management regulations can be evaluated. If stream conditions can be adequately determined and predicted with these methods, it may be ultimately possible for land managers to develop site-specific prescriptions with simple stream survey information and predictive relationships developed through monitoring and research applied by stream type.

In order to use the classification and monitoring program to evaluate the adequacy of forest practice regulations or to develop more sophisticated management prescriptions than are currently possible with regulations, research and monitoring efforts must be coordinated relative to the stream typing system. It will be necessary to coordinate research efforts with CMER technical steering committees and other research organizations that will establish the relationships between 1) management activities and changes in watershed and riparian conditions, 2) ecological communities to local environments and response to changes, 3) key channel characteristics and basin scale processes, and 4) aquatic productivity and basinwide distribution of habitat conditions.

Products

1) Methods to map segment types

2) Variables and survey methods to determine current stream conditions (response variables).

3) Indices to interpret current levels of input variables that will allow prediction of direction and magnitude of change with forest practices.

4) Methods to determine the influence of forest management on streams of a given type.

5) Predictive tools for basin and site specific planning.

6) Method to assess cumulative effects.

MONITORING PROGRAM

INTRODUCTION

As stated in the General Introduction, the Ambient Monitoring Field Program is essential for successfully meeting the goals of the TFW agreement, primarily by providing reliable, consistent information needed for adaptive management. Adaptive management, using the tools of research and monitoring, is the process that allows us to make changes in land management actions based upon a growing understanding of the dynamic relationship between land-use activities and public resources sustained by streams and forests. We need reliable information and an interpretive system that allows us to effectively use this information. The AMSC's monitoring program, described in the following pages, will serve that critical need. Through it, new insight into resource dynamics that result from focused TFW research projects, can be applied statewide with reliability. Ultimately, the AMSC hopes to establish a standardized statewide program to provide data on resource status and resource trends. The information derived from this program, when used with the landscape classification system described in the preceding section, will allow us to predict the probable outcome of certain management prescriptions on watersheds.

In addition, we understand that many of the resource managers in the field want to see a program that provides them with information that is of immediate use in their day to day work. Understandably, the needs of this diverse group will be quite variable. We have tried to respond to this need by offering to develop a series of optional monitoring modules from which standardized protocols can be chosen and applied at specific locations where a more detailed level of investigation into the status of a resource parameter is desired. This approach will be presented as a separate program element later in this document. We cannot reasonably start on this optional element until and unless we get the statewide program started and adjusted. Thre are also some lingering questions as to how this sort of effort might fit into the overall monitoring program and how it would serve the fulfillment of the larger TFW objectives. We try to present some of these in our closing remarks.

PROGRAM RATIONALE

There has been much discussion within the AMSC regarding the purposes of monitoring and the many uses of information generated by the program. This program should be useful at both the local and statewide levels. One aspect of a statewide program such as this is that it will provide evidence of change over time in certain key indicators at the local level. Just the process of documenting these changes in important variables allows for comparison between observed values in different watersheds with similar characteristics. In the broader sense, at the state-wide scale, information from the various ecoregions will allow for comparisons between distinct ecoregions, and add to our understanding of how key variables change over time and at different locations.

PROGRAM DESCRIPTION

There is both a long-term and a short-term strategy for this monitoring program. In the long run, the program should provide important information about the current status and trends in key habitat features associated with streams and riparian corridors. It will provide the basis for more intensive investigation of cause-effect relationships highlighted by the trend data mentioned above. It will also provide the important conceptual framework through which research results can be reliably applied to streams within dissimilar ecoregions. This is the important link with the multitude of CMER sanctioned applied research projects. Also, this classification system and conceptual model will be very useful as a predictive tool to describe the nature and magnitude of change in instream resources that respond to land disturbances within the watershed.

Our short-term strategy is to successfully initiate this program at the statewide level, during the 1989 field season. We have developed a pilot program for immediate implementation this summer that will provide data that will become the foundation of the complete expanded monitoring program.

Goals and Objectives

The AMSC, with assistance from the other participants to the agreement, has identified several broad goals that serve the needs of TFW through adaptive management. These have been discussed in detail in the General Introduction.

For the purposesof our monitoring program, the long-term goal of immediate importance is to monitor the effects of forest management activities on physical features and biological resources of land and water ecosystems within Washington. Although it may not be immediately apparent, the monitoring program is designed to provide the essential foundation for achieving this goal. Its success is linked to fully integrating the applied research efforts of other TFW sanctioned projects.

In the short-term, the program will focus on three important objectives:

1) Establish a statewide monitoring program, that will include standardized field procedures applied in a consistent fashion, and ensure consistency with established scientific study design principles;

2) Identify baseline conditions, trends, and variability in key ecosystem features and diagnostic response variables, that are sensitive to land-use impacts, eg. instream habitat characteristics;

3) Gather important information needed to develop, test and refine the stream classification system - this will allow us to test the suitability of our sampling methods and selected variables, as well as helping in the refinement of our study design.

Pilot Monitoring Field Program

As stated in the introduction, there are two major aspects of our AMSC program. The first aspect involves the statewide program as described below:

In the short-term, the first aspect is called our "pilot project for 1989". It will take place at the state-wide level, and has two important features:

a) it will focus on key elements needed to test our stream classification system, and

b) include a number of "response variables", which are key physical and related habitat variables, sensitive to land-use practices that may indicate of the inter-relationships between land-use and instream resources, (these might include, as examples, such things as channel stability, flow, sediment, and large woody debris in the channel).

With the help of the CMER committees, we will identify these key variables, the appropriate methods and provide training in their use to interested cooperators.

By including these elements in a state-wide program, we hope to lay the foundation for a substantial body of baseline information upon which the program will grow in future years.

Short Term Tasks

The approach for this first year's pilot phase of the monitoring program involves a number of tasks. The attached project timeline shows what needs to be done and the relative timeframe for completion. As you can see, the time available to complete each task in succession is very short. Within the next several weeks, criteria for study site selection and specific variables to be measured in the field will be selected. Standardized methods for measurement or sample collection will then be identified. Equipment lists will be prepared, training sessions will be scheduled to train cooperators willing to do the field work, and a field methods manual will be completed.

Study Design Considerations

Once the variables have been chosen, an appropriate study design will be developed, that includes a statement of the hypotheses being tested, the appropriate sampling strategy, and the analytical and statistical tests to be applied to the data. We have arranged for a biometrician to assist in the design and analysis considerations.

Our initial objective is twofold: to be able to reliably measure change in certain key response features of land-aquatic systems and to test the validity of our stream classification scheme. Detecting trends requires an understanding of present or baseline conditions. We want to be able to distinguish change in these various parameters that is attributable to natural causes, and that which seems associated with land-use activities. Differences between and within distinct ecosystems will be discernable once we have some confidence in the predictive capability of our classification model. When we select sampling sites, we will need to account for the fact that most available stream sites will have some history of land-use disturbance activities. If we are successful, the land/aquatic classification system will provide a predictive tool that will allow us to anticipate the likely consequence of certain land-use practices within a given watershed by virtue of its distinctive characteristics. We will provide details on the specific design aspects as they are developed.

Selection of Monitoring Variables

The AMSC program is designed to guide the collection of information about several important variables that are sensitive to land-use impacts, and that will be broadly useful to TFW when integrated through a classification system. We have identified a number of these such as streamflow/hydrology and water quality, that will be included in a field manual made available to TFW field participants. These are variables that should be measured regardless of the objectives of a particular research or monitoring project, because these critical variables can be used to develop a better picture of a watershed's current status and to identify possible trends in resources. They are considered as the fundamental elements, the building blocks, of a larger, long-term monitoring endeavor. Those dealing with physical channel features, ie. channel geomorphology, make up the core of the classification system-related variables that are essential to the statewide program. More work needs to be done to refine this list so that it contains only those elements that are known to be important to the immediate monitoring objectives.

The tentative list of variables include:

1. Channel morphology - physical features at the channel unit and segment scale, such as bank stability, channel width, gradient. Methods to measure these are fairly well-defined, but will require careful training.

2. Temperature - the geographic range of the current temperature monitoring efforts could be extended to include stream index sites.

3. Large woody debris - methods to measure this important channel feature are well established. This would provide important links to the riparian zone studies.

4. Water quality - this may initially be limited to conductivity and other parameters easily determined. Other important constituents such as nutrients, forest chemicals, and similar indicators might be appropriate to measure on select sites, at the more intensive level.

5. Sediment - the focus should be on some general index of sediment such as bedload composition, shifting, or annual sediment budget.

6. Biological/physical habitat - features important to instream life forms such as detritis accumulations, presence or absence of invertebrates and vertebrates, algal growth, should be a part of this early effort.

7. Flow and Hydrology - We know this is important but are unsure as to the focus at this time. In areas where no historical flow records exist, and no recording guage has ever been installed, a standardized method could be used to synthesize an annual hydrograph. This area needs further definition.

Optional Monitoring Variables - Modules

As discussed before, in setting policy and making appropriate decisions regarding resource management, a variety of questions and issues may arise in a local situation, and surveys, monitoring or applied research programs may be desired to further develop plans or procedures of immediate importance. We intend to make available standardized methods in these areas that can be used when local interests desire to take the investigation beyond a

cursory level of monitoring. We expect that many of the procedures will be derived from field studies evaluating the effects of forest practices on resources conducted by other CMER committees. Along with the other committees, we will develop these methods and assist TFW cooperators in using them.

Program Rationale

There are a variety of management actions that may need technical information in order to make appropriate decisions (such as resource management plans, interdisciplinary teams, identification of corrective action projects) or to evaluate the effectiveness of past decisions (forest practice revisions, annual reviews, etc.). These analyses will require standardized methods and field procedures to assure adequate information is used for decision-making related to specific resource issues or questions.

There are some important considerations in gathering information for these purposes:

1. Appropriate variable(s) are measured to answer questions based on well conceived hypotheses, established relationships, etc.

2. Quality control must be assured by incorporation of a self-checking procedure.

3. The level of confidence associated with the information needs to be well understood. This would be included in the overall study design and analytical protocols developed for this purpose.

TFW Application

We see these methods as modules that are designed to address specific questions or perceived needs. These can be selected by users as the need and resources arise. The users of our optional modules must recognize that methods may change in the future as better understanding is developed in the research and monitoring program and with experience gained through field trials.

The AMSC recognizes that there will be considerable discussion of methods, disagreement about reliability of information in interpreting resource conditions, and reluctance to recommend resource assessment methods without a sound interpretive basis. While it is important to provide managers with the means to assess resources now, it is equally important that such data not be used beyond its reliability with TFW. It will be important to develop a consensus on methods and interpretation as is the case with our pilot field monitoring program. We expect to provide the same level of study design oversight as will be applied to the general statewide program.

Goal:

The goal of this element is to provide a standardized set of methodologies for collecting and interpreting resource information in a manner useful and understandable to those involved in TFW decision-making.

Strategy:

We will coordinate identification of these methods with CMER technical steering committees and related constituents. Determine the needs from discussions with the

participants, and compile methods on parameters of interest through literature review and consultation with practitioners. Further research may be needed to develop appropriate sampling methods if those currently available seem inadequate. We will develop training programs and workshops and assist in providing the tools for analysis.

ROLES, RELATIONSHIPS, AND RESPONSIBILITIES

The monitoring program of the ambient monitoring workplan requires participation by local TFW cooperators at several levels. The AMSC will develop and provide oversight of the statewide monitoring program described previously. Interested local cooperators will tailor the design and implement watershed/local monitoring programs following AMSC recommended guidelines. Local programs may include additional variables to address local conditions, as well as the variables needed for the various purposes of this years pilot project. Guidelines for study site selection will be provided by the AMSC.

The AMSC and it's coordinator will assist in the development of watershed monitoring programs by providing training and technical assistance, as needed. A program for assurance of quality in data collection and processing will be developed. Copies of the data will be kept with the local cooperator as well as in a central repository to be determined by AMSC and the Information Management Steering Committee. In addition, the coordinator will keep a data directory that provides information on study site locations, types of data collected, and local contacts.

Local cooperators will be responsible for analysis and interpretation of data needed for comparison of stream reaches within and between ecoregion and for statewide analysis of trends. The AMSC will disperse information for regional or statewide applications.

PRODUCTS

We will produce a field manual that contains:

1. A description of stream, riparian, terrestrial variables, sampling methods, and appropriate analytical techniques and design elements.

2. Any available interpretive or predictive relationships that can be applied in evaluating survey information.

3. A description of the appropriate application of resource information gleaned from this program, to the TFW adaptive management process. This discussion will establish confidence levels on the use of resource data in assessing management effects or in resolving conflicts based on the current state of our collective understanding.

BUDGET

Much of the preliminary work described above will be done with funds appropriated for FY 1988-89, ending on June 30, 1989. Additional funding for July through June, 1991, in the amount of $180,000 / year has already been requested from the legislature, via

DNR legislative budget request. This should allow for the program to respond to anticipated needs in subsequent years. Additional in- kind contributions will continue to be made by many of the cooperators.

UNRESOLVED ISSUES

Before we can take the ambient monitoring program further towards the realization of its long-term potential, important discussions need to occur and decisions made regarding a number of issues critical to the nature, scope and ultimate utility of the program. From our collective perspective, the few issues presented below should have priority if and when such discussions occur:

Interpretation and Response

One item that has received considerable debate within the Ambient Monitoring Steering Committee is that of how information gleaned from the program will be interpreted. For instance, resource trend information will identify specific changes in key variables, but does not indicate when those changes reach critical levels of concern. Unfortunately, this important discussion of what standards for key variables are to be targeted has never been resolved at the appropriate level within the TFW hierarchy. For many variables related to fish production and aquatic ecosystems, there are no regulatory standards, The TFW agreement did not identify any procedure to reach concensus on the adoption of thresholds or resource standards. The AMSC does not have the authority to set these standards. The continued lack of these important standards or thresholds are likely to create controversy in interpreting trend monitoring data. Is the monitoring data going to be subject to different interpretations by various interests? Ideally, its earliest usefulness will be at the local level, providing information the local biologist and land manager can incorporate into their management planning. But will there be consistency in how this information is used? This anticipated controversy over interpretation will likely have to escalate up to the TFW policy level to be resolved, if no process is set in motion to address it before that time.

Eventually, through adaptive management, some action or response will be triggered by the information collected. At present it is unclear in what forum, and by what process the decision to make a change will be made. Does the monitoring program perform strictly an information gathering function, merely providing trend data to managers and policy makers who then decide what to do? Or should the AMSC provide the interpretation and make recommendations to the TFW participants as to the appropriate actions?

Cause-Effect Relationships

Monitoring information on instream and riparian resources alone does nothing to elucidate the causes of the observed changes. An approach to deal with this is to develop specific controlled research projects or more focused intensive monitoring effort to determine cause and effect relationships. It is likely that once a "monitoring" program is in place, there will be circumstances when a relationship between observed change and proximal cause will be obvious and require little further investigation. Other relationships will be much more obscure and more difficult to document. Eventually, we will need to refine some aspects of the program to respond to this need by examining the direct cause-effect relationship between forest practices and changes in resource condition. What role will the more intensive level investigations using the modules alluded to above, play in the overall pool of information at the statewide level?

SUMMARY

The approach for setting up a statewide stream sampling program and classification scheme has been described in the previous sections. These are formidable tasks that require the support and cooperation of all of the parties to the TFW agreement. The program for this initial period may require refinement and creative response to unexpected problems in the process of field implementation. Eventually, information from this pilot project will provide the basis for an overall monitoring effort that should yield baseline information that will allow us to:

1. develop and verify a stream classification scheme that will serve as a tool to predict the consequences of land-use impacts on streams and riparian corridors; and

2. determine the changes in the physical, chemical and biological characteristics of streams, and be able to differentiate between those changes that likely occur naturally and those that result from land-use practices occurring within the watershed.

We would welcome an open discussion of the unresolved issues noted above before we get too far into the planning of future research and monitoring programs.

ACKNOWLEDGMENTS

We would like to thank the basin analysis workshop participants (June 1988) for sharing their thoughts on classification and related topics that has helped us to achieve what we hope is a balanced perspective of classification and its use in resource management embodied in this workplan.

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Figure 1. Examples of stream and terrestrial environments that have unique physical features and distinct habitat characteristics.

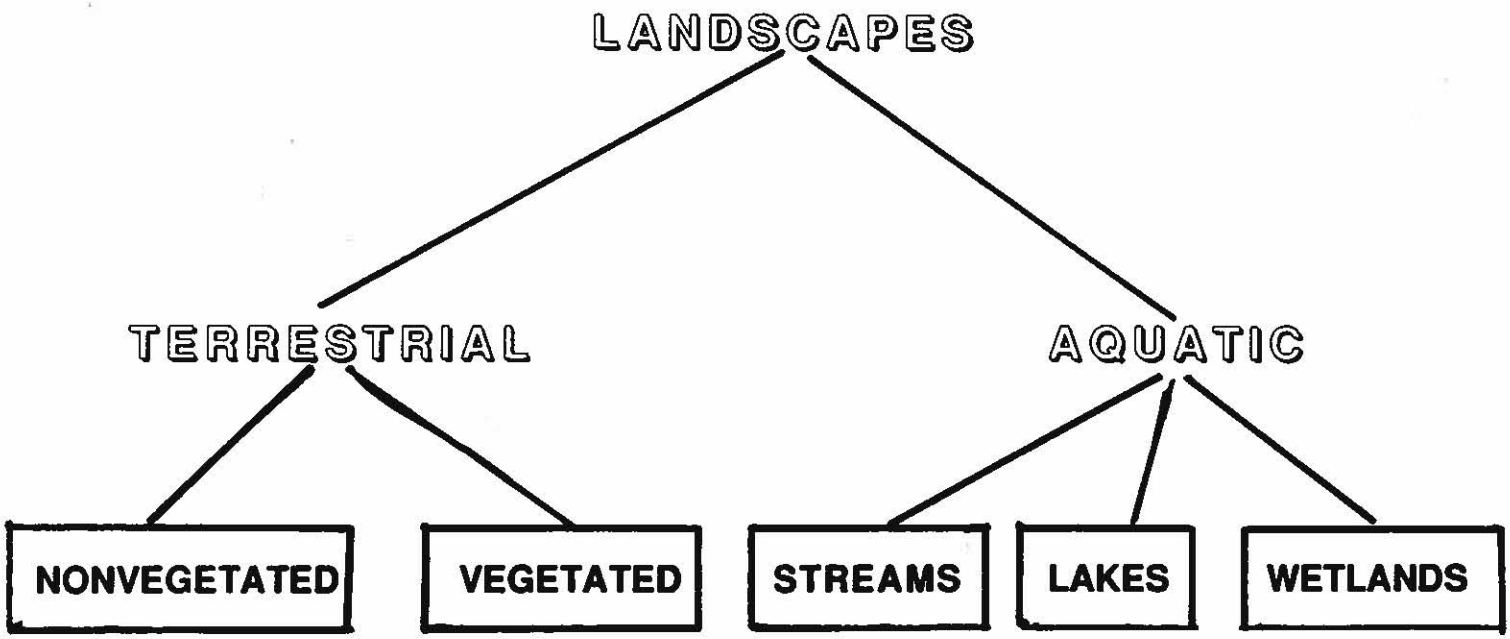


Figure 2. Revised ecoregion map of Washington based on dominant bedrock geology.

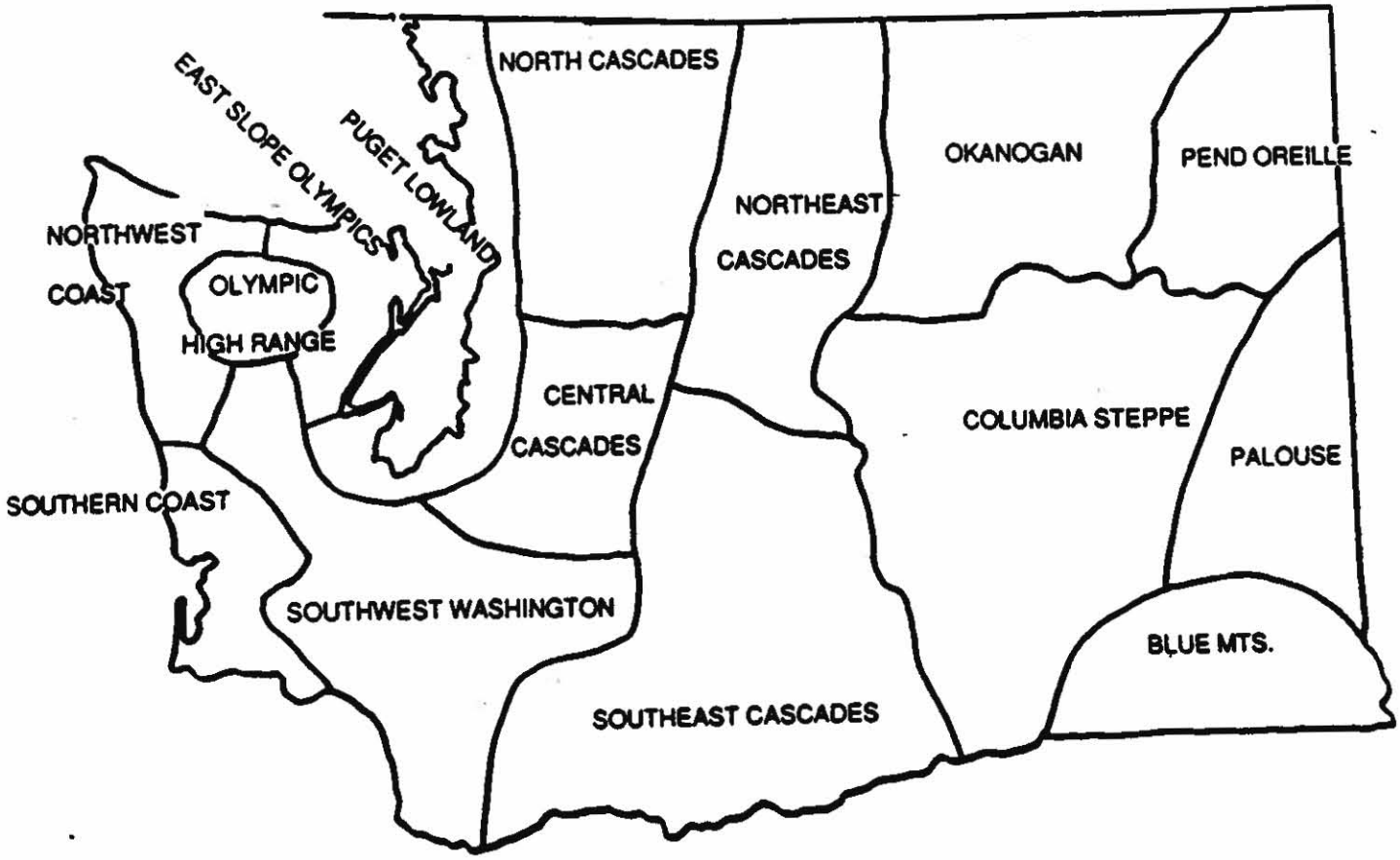


Figure 3. Example sketch of geohydraulic zones within a basin.

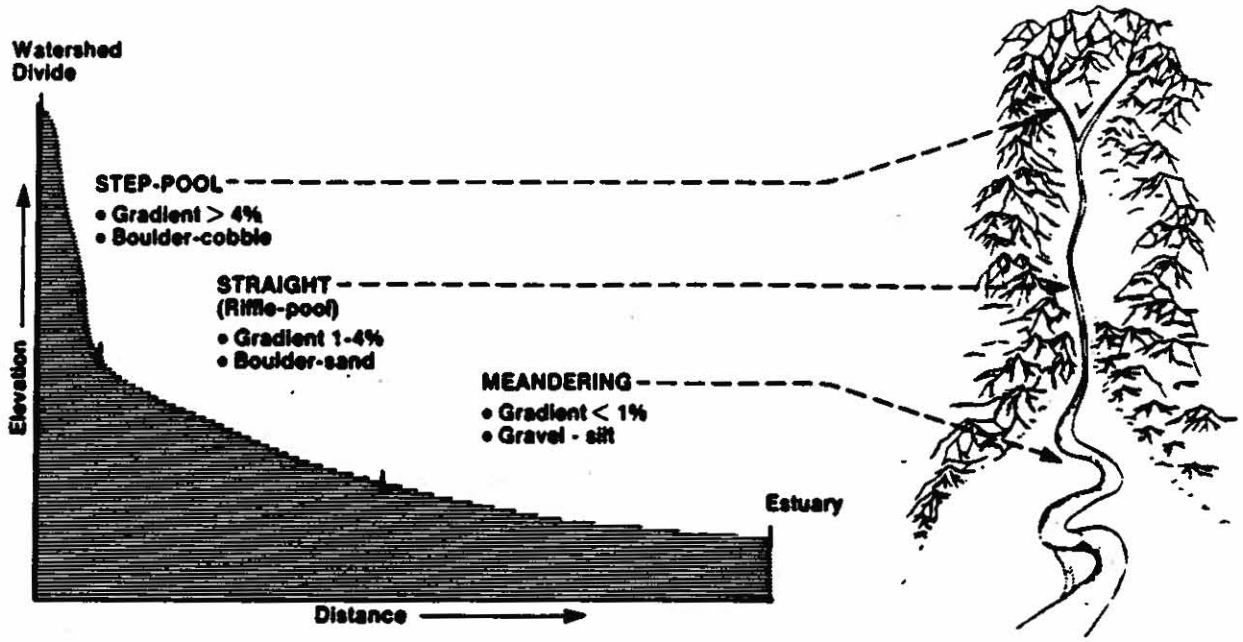
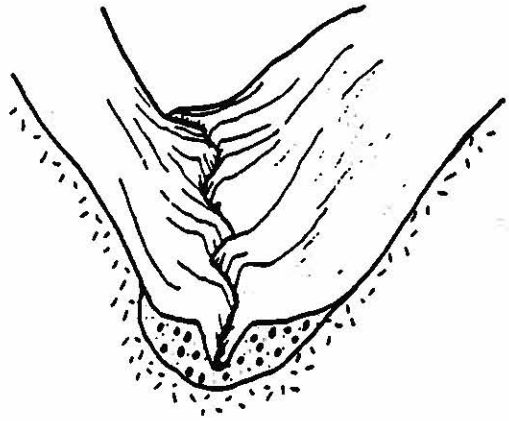


Figure 4. Examples of segments defined by Cupp (in press).

Code	Segment Type
5	Incised Glacial Till or Incised Colluvium Deposits



Distinguishing Criteria

Stream Order: 2, 3, 4

Valley Width: 1-2X ACW

Side Slopes: immediate stream adjacent slopes moderate to steep due to downcut through glacial til and colluvium surfaces upper slopes tend to grade from flat to steep as elevation is gained

Land Form Feature: streams downcutting through glacial deposits or colluvium originated substrate; advanced downcutting has led to steep to moderate stream adjacent slope with poorly consolidated upper bank material; this leads to moderate to high potential for bank failure

Other Common Characteristics

Substrate: generally rubble/boulder; banks are generally composed of unsorted glacial drift material or colluvium deposition

Channel gradient: 2%-5%; alluvial deposition reduces the gradient to 0-3% in localized reaches

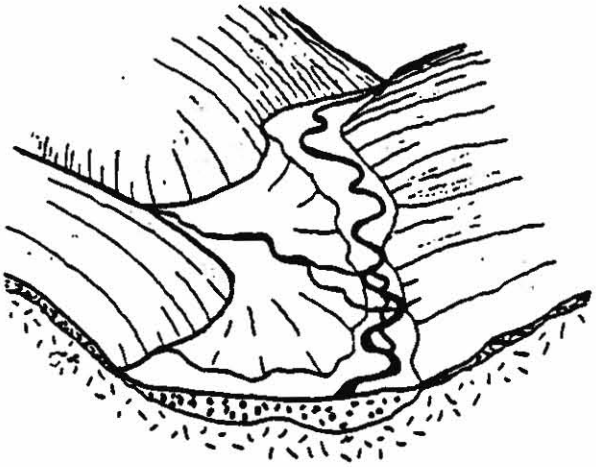
Channel Type: boulder confined

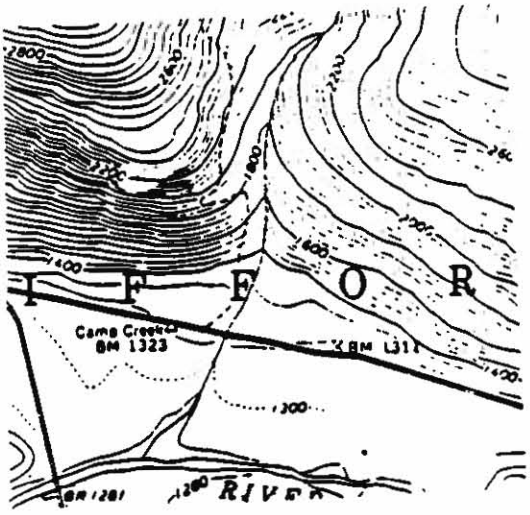
Channel pattern: straight to sinuous; occassional braids; moderate to high meanders through alluvial deposits

LWD: variable, often abundant single stems and occasional jams; jams and stems are commonly deposited in high flow areas and where they contribute little to perennial habitat

FIG. 4. cont.

Code	Segment Type
2	Alluvial fan





Distinguishing Criteria

Stream Order: alluvial fan from large 2nd, 3rd 4th order tributaries deposited on valley floor and alluvial terraces of 5th and 6th order stream

Valley Width: greater than 3X ACW, but may be more confined in upper portions of the fan where the stream exits the canyon more confined in places

Side Slopes: flat to moderate, although the upper end of the alluvial deposition may be in lower incised valley

Channel pattern: moderate sinuous meanders, occasional braids

Land Form Feature: stream travels through its own alluvial fan deposition on large 5t and 6th order valley floors; the upper end of these segments may be located in the lower stretches of incised valleys and canyons; stream actively downcuts through unconsolidated banks in moderat gradients

Other Common Characteristics

Substrate: boulder, big boulder deposited in upper fan, while smaller rubble and cobble substrate predominate in lower low gradient sections

Channel gradient: 1%-6%

Channel Type: alluvial

LWD: frequent large jams and individual stems often deposited in high flow channel, but only occasional small jam and embedded individual stems create high quality pools and spawning sites

Figure 5. Conceptual diagram of watersheds as a series of linked segments. Segment boundaries ofter occur at changes in valley gradient induced by geomorphic landforms, bedrock outcrops, etc.

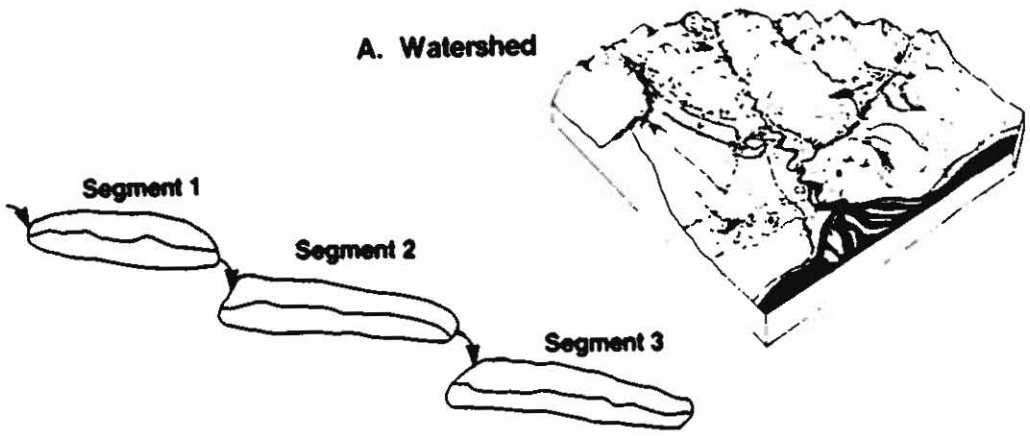


Figure 6. Schematic of influence of environmental input factors on segment characteristics.

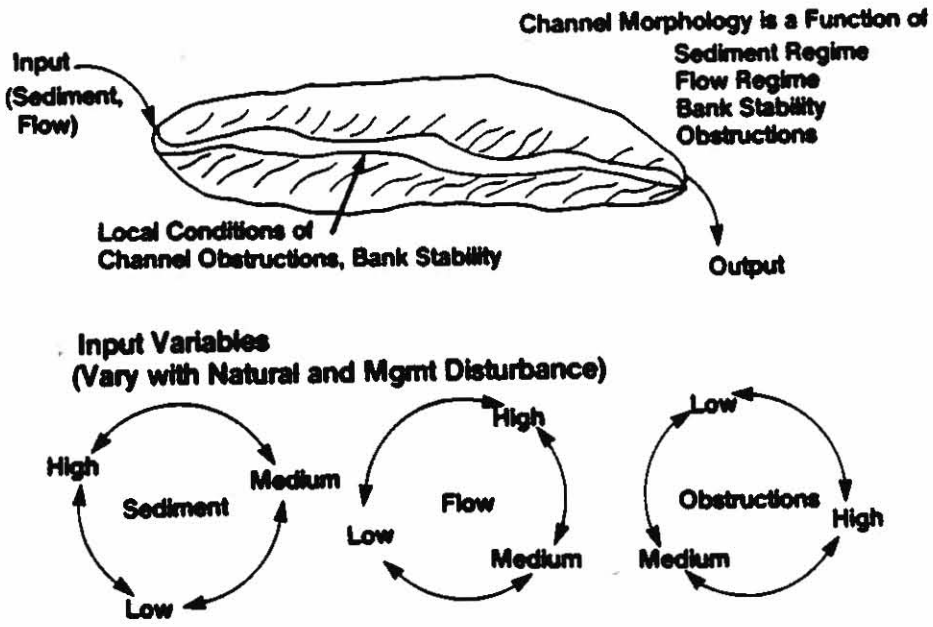


Figure 7. Example of environmental indices of a segment reflecting current sediment, flow and obstruction characteristics.

SEGMENT TYPE_____

BASELINE CONDITIONS

ENVIRONMENTAL INPUT FACTOR	RELATIVE RATE		
	HIGH	MEDIUM	LOW
SEDIMENT	X		
FLOW	X		
OBSTRUCTIONS		X	

Figure 8. Schematic of cumulative watershed effects. Material such as sediment of flow introduced within the system is transported from segment to segment with different rates of storage. Within segments, material moving through may produce different characteristic response depending on limits determined by segment.

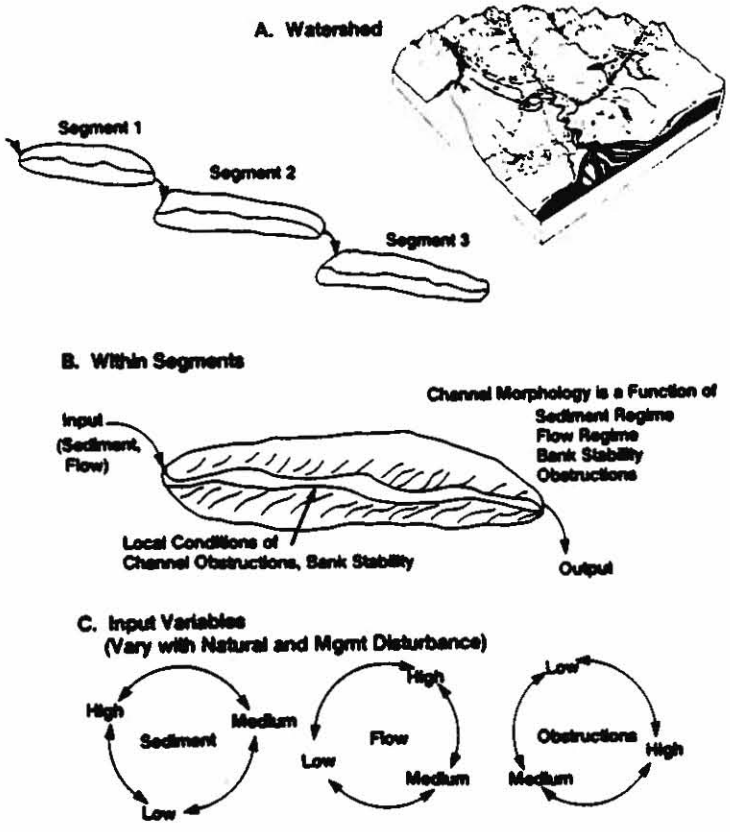


Figure 9. Physical channel and flow conditions characteristics of segments determine habitat availability in each segment.

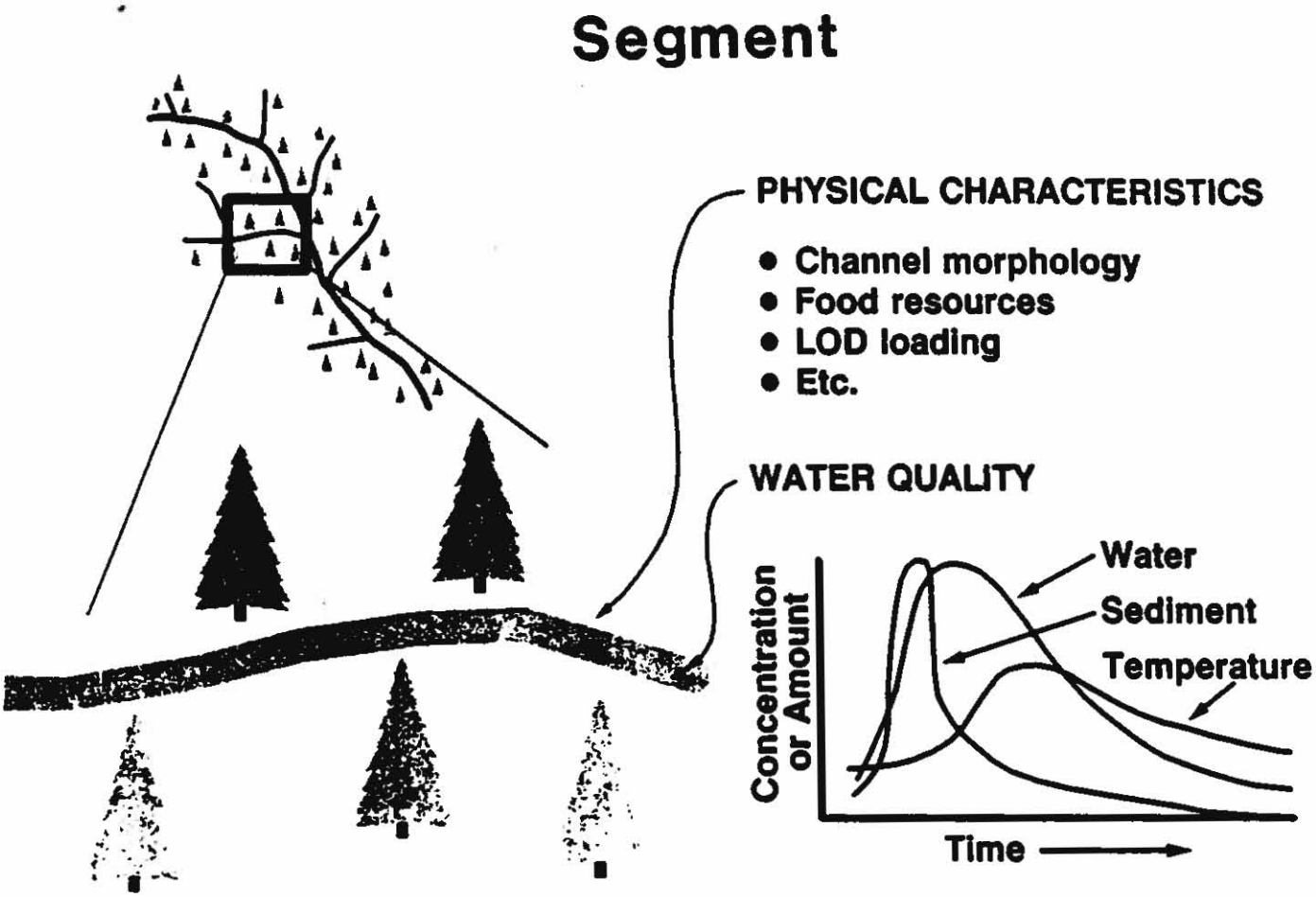


FIG. 10. ESTIMATED TIMELINE FOR PILOT

1989 AMBIENT MONITORING FIELD WORKPLAN

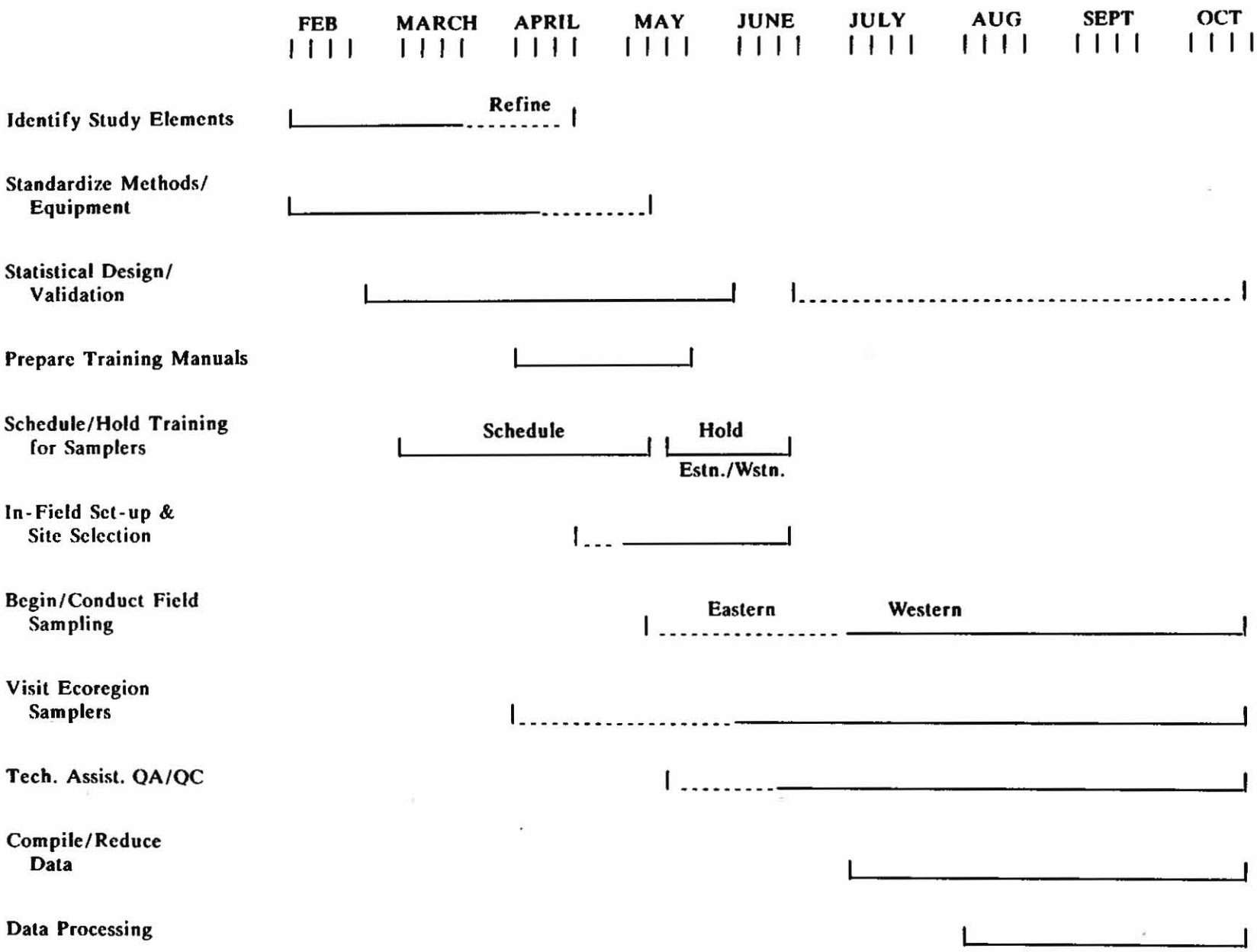


Table 1. Stream class strata

Classification Level	System Stratification Level: Class Units (examples)	Physical	Fisheries	Persistence
Ecoregion	North Cascades Blue Mountains	Regional geology Climate Natural vegetation	Species array	>10,000 yrs
Stream Order/	Orders 1-7	Stream size, basin area	Life history stage	>10,000 yrs
Geohydraulic zones	Meandering, step-pool, straight	Valley slope, particle size	Life history stage	>10,000 yrs
Segment	Alluviated valley, incised valley	Hillslope/valley/ stream interaction	Populations (volume of habitat)	>10,000 yrs
Channel Units	riffles, pools	Sediment and water in response to bed and bank conditions	Individual organism (fish)	1-10 yrs
Microhabitat		same as above	Macroinvertebrates	1-5 yrs

Table 2. Factors important and stream formation and classification levels selected to account for major factors.

FACTOR	CHARACTERISTICS	CLASSIFICATION LEVEL
GEOLOGY	BASIN SUBSTRATE DOMINANT SEDIMENT DELIVERY PROCESS	ECOREGION
CLIMATE	ELEVATION PRECIPITATION (AMOUNT & TIMING)	ECOREGION
VEGETATION TYPE	ECOZONES, HABITAT TYPES	ECOREGION
WATERSHED SIZE	DISCHARGE, WIDTH, DEPTH DRAINAGE AREA	STREAM ORDER/ GEOHYDRAULIC ZONE
VALLEY CHARACTERISTICS	VALLEY GRADIENT CONFINEMENT	SEGMENT

Table 3. Examples of diagnostic (defining) characteristics of stream classes for levels of the classification scheme.

CLASS	VARIABLES	CLASS TYPE
ECOREGIONS **(OMERNIK & GALLANT)**	CLIMATE	
	POTENTIAL NATURAL VEGETATION	MAPPING
	SOILS	
	LAND SURFACE FORM	
STREAM ORDERS/ GEOHYDRAULIC ZONE **(STRAHLER, BAUER)**	STREAM ORDER	
	BROAD GRADIENT CLASSES & CHANNEL PATTERN	TYPING
SEGMENTS **(CUPP, ROSGEN)**	CHANNEL WIDTH/VALLEY WIDTH	
	CHANNEL GRADIENT	
	DOMINANT PARTICLE SIZE	MAPPING
	SIDE SLOPE GRADIENT	
	SINUOSITY	

Table 4. Examples of response variables that change with environmental input variables.

CHANNEL UNIT DISTRIBUTION
WIDTH/DEPTH RATIO
BED MATERIAL SIZE
CHANNEL PATTERN (BRAIDED, MEANDERING, STRAIGHT)
INDEX OF BANK STABILITY
ROUGHNESS INDICATOR
THALWEG GRADIENT