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Adaptive Ecosystem Management in the Pacific Northwest

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ABSTRACT

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A systematic approach to adaptive management is proposed to simultaneously manage at the regional, provincial, and watershed scales and to reorganize the activity of agencies to better support the concepts of adaptive management. Reorganizing management activities into these four groupings is recommended: adjustment (expanded decision-making); linked, not single actions; feedback, including monitoring; and information synthesis. A major new focus for the collaborative decision process is to identify and set priorities among possible future adjustments. Linked actions that integrate management and research would then be designed to produce the information needed to decide whether to make proposed adjustments. Feedback and information synthesis will follow to facilitate and inform future decisions. The strategy requires making better decisions; improving public participation; and developing science-based management.

Keywords: Adaptive management, feedback, adjustment, future decisions, linked actions, management experiments, information synthesis, decision support, science-based management, public participation, the lacing model.

SUMMARY

In this report, we seek to clarify the philosophy of adaptive management as it could be applied to Federal lands in Oregon, Washington, and northern California. The report does not attempt to suggest standards and guides for the whole region because they would hinder the development of creative approaches to adaptive management. The next step is to build interagency adaptive management systems for each provincial planning and analysis area-as defined by the Record of Decision (ROD 1994)--following the broad guidelines in this report.

Elements of adaptive management-feedback and adjustment-have been practiced in past management. More rapid and effective learning is now needed to increase the probability of desired outcomes. We propose a strategy to improve management by:

- Making better decisions;
- Improving public participation;
- Developing science-based management; and
- Using a systematic approach.

A systematic approach to adaptive management is proposed to simultaneously manage at the regional, provincial, and watershed scales and to reorganize the activity of agencies to better support the concepts of adaptive management. We recommend reorganizing management activities into four groupings that support the desired function of the whole system:

- Adjustment (expanded decision-making);
- Linked, not single actions;
- Feedback, including monitoring; and
- Information synthesis.

A major new focus for the collaborative decision process is to identify and set priorities among possible future adjustments or decisions. Linked actions would then be designed to produce the information needed to decide whether to make proposed adjustments. Feedback and information synthesis will follow to facilitate future decisions.

Authority to make adaptive ecosystem management work lies with the Regional Interagency Executive Committee and the Regional Ecosystem Office. Allocation of funding is an important mechanism for optimizing the system's functioning. This approach to management represents a change in strategy, emphasis, and participants. Two newly formed groups, the Interagency Resource Information Coordinating Committee and the Research and Monitoring Committee, will play major roles. Implementation in the provincial planning areas will be the responsibility of participating agencies.

CONTENTS

PART I. BUILDING AN ADAPTIVE MANAGEMENT SYSTEM

Introduction

Adaptive management, which is required in the Record of Decision for the President's Forest Plan, applies to all Federal lands covered in the Plan, not just to Adaptive Management Areas. Controversial practices will likely be tested on Adaptive Management Areas, but adaptive management on other lands will provide vital information as well. For example, adjacent Federal and non-Federal lands might be compared in collaborative experiments with non-Federal owners. Watershed restoration outside Adaptive Management Areas should also use adaptive management principles.

We have not sought to establish specific standards and guides for adaptive management of Federal land in the Pacific Northwest; rather, we define broad constraints under which diverse approaches to adaptive management can be implemented. We recommend that an adaptive management approach be used to develop specific standards and guides in each of the provinces. **Provinces,** as used in this report, are the provincial planning and analysis areas defined in the Record of Decision (ROD 1994). The role for regional managers is to encourage a diversity of approaches, ensure that implementation is documented, and analyze successes and failures within each province. A natural variation in approaches will emerge. and this variation should be promoted within these broad guidelines to provide a breadth of experience to improve approaches at all locations.

The adaptive management system described in this report establishes a framework for combining resource-information management, monitoring, research, planning, public participation, and watershed analysis. This publication is based on the reports of the Adaptive Management Process working group, commissioned by the Regional Interagency Executive Committee as part of a larger effort to implement the President's Forest Plan.

<u>Review of adaptive management concepts</u>

The term "adaptive management," as used by Holling (1978) and Walters (1986), was adopted in the President's Forest Plan as a sequence of planning, acting, monitoring, and evaluating (fig.1). The concept of adaptive management is being widely debated and is taking on different forms and definitions. Various perspectives on adaptive management are rooted in parallel concepts in business (total quality management), in experimental science (hypothesis testing), and in systems theory (feedback control), to mention a few. All of these views of adaptive management have a common thread: feedback and adjustment. **Feedback** is knowledge or data on the effects or results of an action, purposefully collected and used to improve future actions. **Adjustment** is using knowledge and data produced by feedback to redirect subsequent action.

Feedback and adjustment are a lot like learning: the importance of experience is recognized and a change is made to reflect experience. Viewed this way, adaptive management is "learning to manage by managing to learn." Beyond this simplistic description, definitions of adaptive management diverge considerably. To develop our view of how adaptive management should be implemented regionally on Federal lands, we first looked at past management from the perspective of feedback and adjustment.

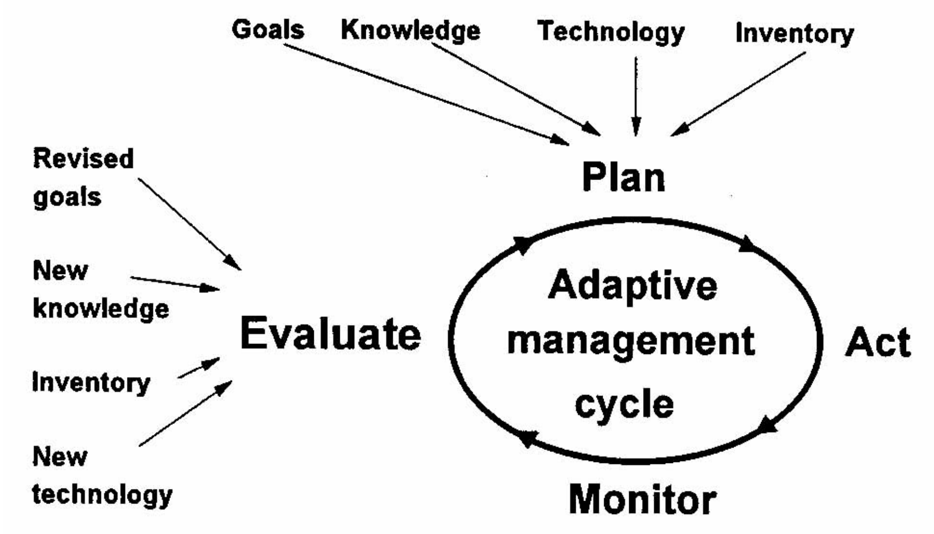

Figure 1-An adaptive management cycle, modified from the FEMAT report (Collopy et al. 1993). Adaptive management is a series of steps structured to promote rapid learning and modify management responsively to meet changing societal objectives and evolving knowledge of ecological systems. For adaptive management to succeed requires adequate, stable funding of all steps.

Feedback and adjustment in the past

The concepts of feedback and adjustment can be found in existing laws and regulations and were often applied in past management efforts. Public involvement provided some feedback to planning through the process specified in the National Environmental Policy Act (1969). The National Forest Management Act (1976) dictates adjustments through National Forest plans every decade. Short-term adjustments can be made through formal amendments or by re-initiating the plans. More dramatic feedback has become commonplace through endangered species listings and court actions, culminating in Judge Dwyer's 1991 injunction on timber sales. Dramatic adjustment followed with the Forest Conference on April 2, 1993, and implementation of the President's Plan. Hilborn (1992) describes this agency approach as "reactive learning." Reactive adaptive management hinders collection and use of feedback because learning-although it does occur, especially during periods of crisis-is not fast enough to deal with quickly changing issues.

Management on Federal lands in the past has resulted in outcomes that were not always desirable-particularly when viewed retrospectively. No management system can eliminate mistakes, but adaptive management-with more rapid and effective feedback and adjustment than in the past-can shorten the time from recognizing a problem to correcting it, so that management reflects new societal demands or new research data. Because ecosystems and people's collective values often change unpredictably, any management target is not likely to endure for long. A system that focuses on rapid learning to adjust to changing circumstances is likely to improve over the long term.

What will change under a new banner of adaptive management? How will these changes become institutionalized? We begin by defining effectiveness of adaptive management as increasing the probability of achieving desirable outcomes.

<u>The need for more effective feedback and adjustment</u>

The need for new approaches to adaptive management comes from more than gridlock. Increasing awareness of change and uncertainty also argue for new approaches:

The world changes rapidly, both socially and ecologically. People see the global environment changing at an increasingly rapid pace-for example, increasing atmospheric carbon dioxide, decreasing global fisheries, and extensive eroding of crop-land. Increasingly rapid societal changes are equally apparent-for example, increased population growth, the dissolution of the Soviet bloc, and separatism spreading from the Balkans. Taken together, these recent changes suggest a broad scope and an increasingly rapid pace for future change, and the need to be able to adapt to changes-many of which are now unforeseen-becomes apparent.

The full ramifications of management actions are unknown. Some land management practices previously thought desirable turned out to be socially or ecologically undesirable when viewed historically. Ecosystems are far too complex to predict future condition accurately. Does this mean nothing should be done until the ramifications are fully known? No, because doing nothing, if that were possible, also has many unknown and poorly predictable effects. Complexity is confronted by increasing effort to understand mechanisms that influence change, by reducing expectations that the future can be accurately predicted, and by reducing risk through diversifying.

"Cookbook" approaches seem easier. People tend to limit their thinking to what they already know. The more an action or process becomes routine and the less it is questioned, the more difficult modifying it becomes when modification is needed. Because information is always changing in unpredictable ways, approaches will always need to be modified. Institutionalizing adaptability requires that people think about and question every decision and every action. Standards and guides are important, but they must be changed when new information warrants a change; new information must be actively sought to change the standards and guides. Thinking about possible future changes that people may need to adapt to does not come easily, but anticipating changes and developing strategies in advance will improve people's ability to respond to change.

A Strategy To Increase the Probability of Desirable Outcomes

Make better decisions

Invest In improved future decisions. Future decisions require more and new kinds of information than now available, even if access were perfect. Actions are needed to produce this information, including pilot-tests of proposed creative solutions. Some of these actions may not appear to have immediate benefit and should be considered an investment for future generations.

Make more-informed decisions. Some important societal, scientific, managerial, and legal information is not readily accessible to decision makers. Facilitating access to relevant information is a crucial step in improving decisions.

Make more-defensible decisions. One reason for increased litigative feedback is that decisions have not been legally defensible. Improving defensibility requires tracking information used in decisions and involving potential litigants before decisions are final.

Improve public participation

Reflect societal values. The perspectives of communities that tended to have a stake in outcomes were sometimes considered in past decisions. Many other communities did not participate in the debate, however, and their views were not known. The democratic ideal of majority rule with protection of minority rights based on the best available information can be approached most effectively through participation by a diversity of people. The more people participate in shaping decisions, the more they will accept the outcomes and take responsibility for them.

Generate new ideas. Experiences of people in business, art. manufacturing, and everyday life are relevant to Federal land management. When ideas based on diverse experiences are challenged through civil and constructive debate, creative solutions often emerge. Managers need to facilitate the debate to tap into this source of knowledge.

Develop science-based management

Design management to produce information. Increasing the probability of desirable outcomes will require better predictions of the implications of current decisions. Science connected to management, science done at the operational scale of management, and monitoring are all required to produce data and theory to improve these predictions.

Include both social and ecological sciences in decisions. Barriers to communication among scientists and between scientists and managers should be removed, and institutional boundaries between research and management blurred. Blurring the boundaries is needed to incorporate scientific concepts such as experimental design into management institutions, and operational relevance into research institutions. The need for credible feedback from research requires that research and management remain independent. Scientists, like the public, need to participate in shaping management decisions and to share responsibility for the outcomes. New mechanisms are needed to ensure that research is more relevant and that results are incorporated quickly into management. People need to overcome their fear of new information; new information may require change, but without new information, adaptive management is impossible.

Test and retest assumptions. People learn by making assumptions and applying those assumptions to the subject of interest. As more is learned, old assumptions are replaced or modified. Assumptions may also require changing because the subject of interest, or its behavior, changes. Ecosystems also change, usually in response to human activities or natural events, and the assumptions people apply to them must change to allow for continual learning. Adaptive management provides an environment in which scientific and managerial assumptions can be tested against alternative assumptions that also describe or allow for observed ecosystem behavior. This ability to test assumptions is the foundation of adaptive management.

Use a systematic approach

Develop an adaptive management system. An improved system of interacting management components is needed to ensure that management agencies work as a whole to achieve defined objectives by using the adaptive management concepts outlined above. A systems approach is also needed to deal with the complexities and tradeoffs of managing at different geographic scales. Institutional resources must be allocated to components of a management system with the function of the whole system in mind.

Improve institutions. Adaptive management concepts should be applied to institutional function as well. The functioning of components and the new system as a whole must be continually analyzed to identify and remove bottlenecks. People responsible for implementing adaptive management need to understand that taking risks is acceptable and occasional failures are unavoidable. Institutions must provide an environment where people will take risks-and acknowledge and learn from mistakes.

The Adaptive Management System

Defining a system based on the strategy as we have outlined is a first step in applying our adaptive management concepts to managing ecosystems in the Northwest. Specific guides based on the institutional framework described in this report must be developed for each province to provide a diversity of approaches.

Twelve components of the system were identified in the FEMAT report (fig.1). "System" implies that the components interact with one another in a way that works as a larger whole. Potential interactions between the 12 components are numerous, and each interaction may be an important process. We sought to simplify the portrayal of the system by combining components into groupings to perform integrated feedback, adjustment, linked actions, and information synthesis (fig. 2).

These groupings are designed to improve consistency between different geographic scales in all activities and to identify which activities are responsible for each step in the adaptive management process. Information synthesis was added as a special grouping, in recognition of the enhanced information needs of an adaptive management system. We are thus elevating information to a status equal to or greater than traditional resources. Groupings are considered below.

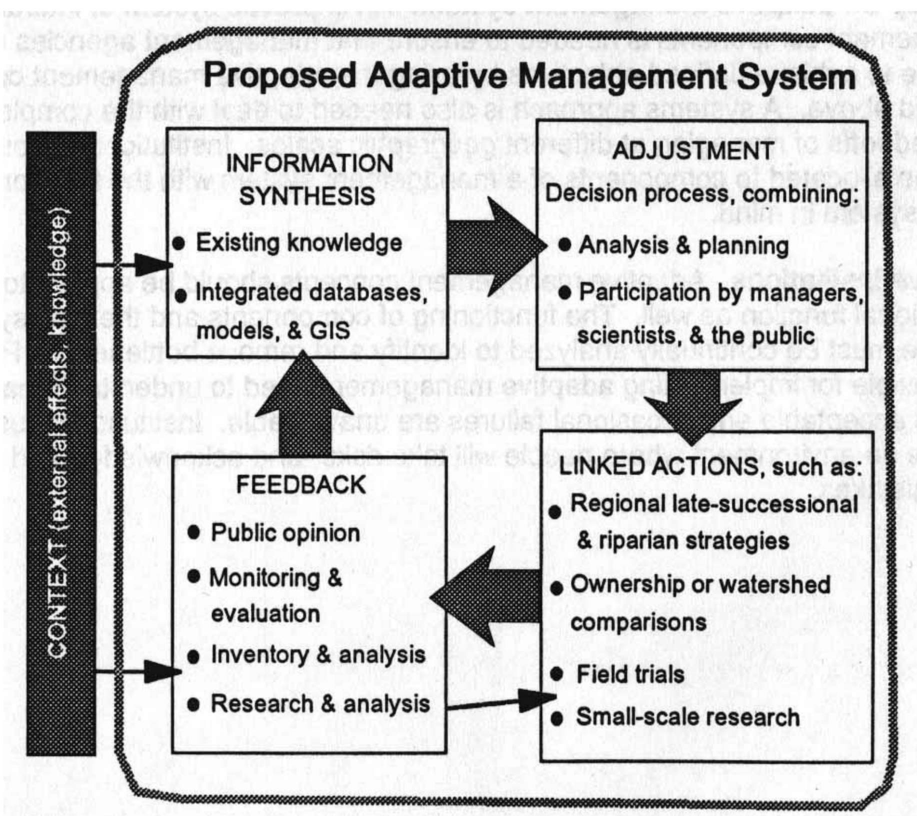

Figure 2-The proposed adaptive management system, modified from FEMAT. Changes include internalizing science and public participation; integrating analysis and planning into an adjustment process; recognizing a wider range of feedback mechanisms; linking management actions, including some research, into a network of related activities where each activity helps to explain responses of the others; and recognizing the importance of information synthesis in this information-rich approach to management.

Adjustment

Deciding when to adjust is perhaps the most difficult task of the adaptive management system. Adjusting when the evidence does not yet warrant it can be as bad as waiting too long. People have much to learn about how to make adaptive management decisions. Designing the adaptive management system to produce and synthesize information will help, but it will ultimately require criteria and rules for deciding when to adjust. Research is needed to develop a "statistics" of adaptive management that includes defining these criteria and rules, and designing management experiments to produce the needed information. Initial approaches to making these decisions should include the following:

Integrating across watershed, provincial, and regional scales. Regardless of the scale of a decision, the predicted effects of each decision on the other scales must be estimated. Predicted effects can be aggregated over time and space, and the analysis provided to managers at all scales. Society's conflicting objectives can be identified and a negotiation process implemented. The idea of the negotiation is, like the interfacing of societal values and ecological capacity, not a matter of redefining the laws of nature, but of understanding the limits, being able to convince others of the limits, and finding creative solutions.

Identifying who is the decision maker. Federal law still requires that line managers are responsible for decisions on Federal lands. Recent interpretation by the courts of the Federal Advisory Committee Act severely limits input from groups that include non-Federal employees, including State employees, yet collaboration is the key to managing ecosystems for objectives that transcend ownership boundaries. Collaboration, coordination, and sharing of information are needed among agencies, adjacent private and industrial landowners; county, State, and tribal governments; scientists; and the public. New mechanisms are needed to make these interactions legal and effective.

Identifying broad societal goals. The first step in any decision process at all geographic scales should be to attempt to identify what society wants, in a general sense. This step was taken in the Forest Conference-where the President identified five principles for managing the forests of the Pacific Northwest-but needs to be continuously re-addressed in the adaptive management process. Finding core values that most people agree to also helps to avoid polarization. The Colville tribe in north-central Washington tried this approach successfully by involving tribal members in defining their quality of life and describing the landscape they desire for the future. They then began to look at what forest practices improved or degraded the defined quality of life. Similar grass-roots efforts in southern Oregon and northern California provide definitions of broad societal goals. At a minimum, these definitions facilitate developing new management strategies. The more that specific actions are the focus and the more these actions are divorced from broad goals, the more difficult achieving societal approval becomes. A societal debate focused on specific actions often ignores the effects of such actions on other societal goals.

Keeping adjustments within national laws. National laws also define broad societal goals, and keeping adjustments within these constraints is necessary to fulfill goals. Recognizing that national laws are not entirely consistent with one another and that laws change as societal goals change is also important. Identifying inconsistencies to policy makers and integrating the intentions set forth in the laws rather than settling for the least common denominator is important as well.

Facilitating an iterative "discussion" between societal interests and the scientific basis for sustainable ecosystems. Because societal values and ecological capacity must be integrated to achieve sustainability, iterative interaction is required (fig. 2). Defining what is ecologically possible is not efficiently pursued without first knowing what people want; reconciling what is desired with what can be sustained and finding creative solutions require understanding what is and is not thought to be possible. Thinking about new possibilities does not come easily, and ideas from a broad cross-section of society are needed.

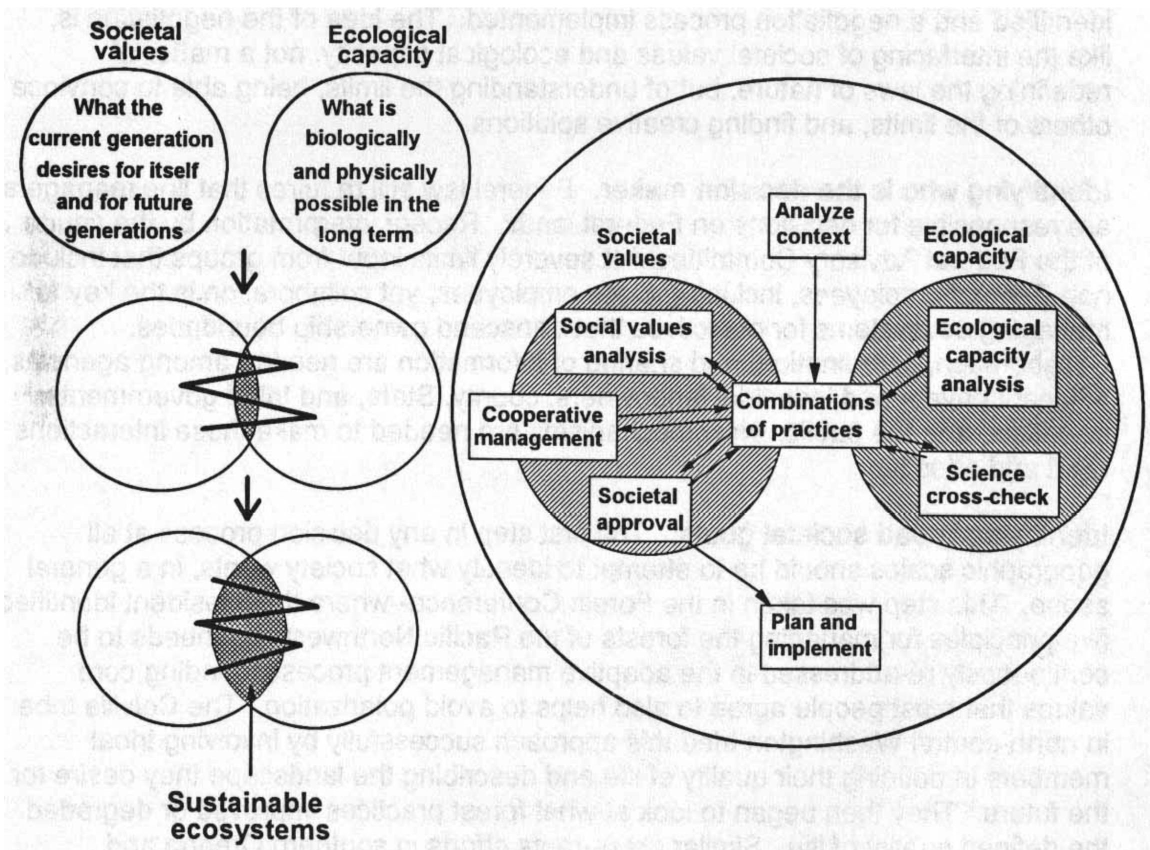

Figure 3-The lacing model represents an iterative decision process (expanded on the right) for any geographic scale to "lace" together societal values and ecological capacity to achieve sustainable ecosystems (Bormann et al. 1994). This model requires that managers, scientists, and the public work together through the steps outlined to achieve the overlap defined as sustainable ecosystems.

Integrating watershed analysis and provincial planning. To the extent that watershed analysis is a synthesis of knowledge about a specific place, watershed analysis belongs in the information-synthesis grouping. If watershed analysis defines what is ecologically possible, then it should be iteratively linked to the decision process. That is, the analysis must be modified as the decision process unfolds, not to redefine the laws of nature but to find creative solutions that seek to achieve what people collectively want and what is ecologically possible in the long run.

Identifying outcomes and measures, in advance. At a minimum, outcomes should be predicted and specific measures of success identified and documented in advance, as a yardstick to evaluate whether the action was successful. Concepts from experimental science and cognitive psychology should be used to develop techniques that help people to see evidence that does not support their preconceived notions. The focus should be more on mechanisms thought to control outcomes than on the outcomes themselves. Focusing only on outcomes quickly results in a cookbook approach.

Using existing information. Decisions must use scientific and societal information available through the information-synthesis grouping. What information is used must be documented and tracked to help justify the action. Having information in a form that can be used thus becomes paramount. Feedback to the information-synthesis grouping is essential in improving the quality of information available for decisions.

Deciding on possible future adjustments. Success in attaining societal goals ultimately depends on whether current management can be designed to produce the information needed for future decisions. Managers, scientists, and the public must collaborate to specify possible future adjustments; management actions, research, and monitoring must be designed to provide information that will improve these adjustments.

<u>Linked actions</u>

Actions are not independent; they must not be thought of as independent. A decision process is needed that produces multiple, linked actions, not single. independent actions. Coordination between actions is essential to connect management at different scales of time and space, and to monitor, study, and ultimately understand management effects. Coordination to support the adaptive management system requires:

Integrating actions across watershed, provincial, and regional scales. Individual actions can be designed to interpret other actions. For example, determining whether the regional strategies for a late-successional reserve system and riparian buffers has succeeded (or failed) by design or by chance will be difficult. If the spotted owl or endangered salmon races are saved, how will people know that the strategy was responsible? Evaluating a range of strategies in watershed comparisons and retrospective studies will help, but any management experiment at a large scale is complex, combining variation in history, environment, species, and managerial objectives. Field trials at the stand or stream-reach scale, with replicated treatments, can be used to tease apart complex factors that combine to influence the watershed comparisons. Ultimately, small-scale research experiments are needed to connect ecological theory to management. Large-scale actions are mainly directed toward management objectives; small-scale actions are mainly directed toward testing scientific assumptions. The designed connections between management activity, watershed comparisons, field trials, and research experiments are more important than the individual activities (fig.4). Information from individual management and research activities cannot be safely extrapolated to different scales without these connections.

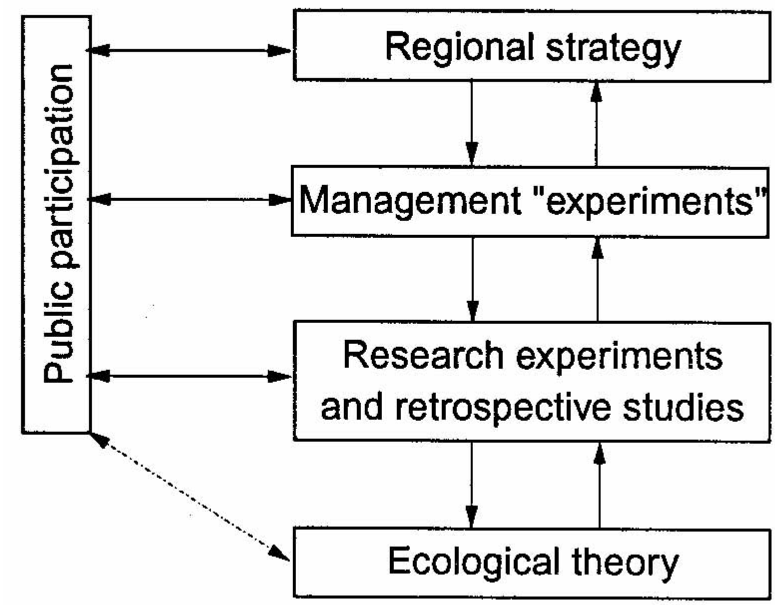

Figure 4--A linked-action plan connects the regional management strategy to ecological theory through management experiments and research experiments and studies testing scientific assumptions (science filters up and management objectives filter down). Public participation is essential in all stages.

Actions linked through time. A series of management actions is often needed to achieve a societal goal or management objective because ecosystems develop over centuries, and ecosystem development is not easily predicted. Coordination between scales and documented commitment through time are both necessary. Difficulties with changing previous commitments should be fully explored and justified.

Feedback

Feedback is more than traditional monitoring; it must include:

A forum for ideas. People need to continually question assumptions and management approaches, and to evaluate management outcomes. Managers need to facilitate "bounded conflict" (Lee 1993), where ideas from a wide variety of people are considered and evaluated on their merits. All views are considered and tabulated, recognizing that many of them are incompatible and cannot be fully accommodated.

Monitoring changing societal views. Changes in societal views should be studied. and existing studies should be acknowledged and used. For example, the Oregon Business Council funded a little known but extensive survey of Oregonians that evaluates, among other things, the importance of the environment to randomly chosen citizens of the State. The Forest Service recently undertook a similar survey on the national scale in an effort to be more responsive to the public. A social inventory and profile of the people and groups that are concerned or may be affected by management actions is needed to better understand their interests and ensure their participation in decisions. Monitoring societal conditions may also help to understand and anticipate changing societal views.

Monitoring management success. What needs monitoring, as described by the interagency Monitoring Working Group, includes implementation (achieving standards and guides), effectiveness (attaining goals), and validation monitoring (testing assumptions arid cause-and-effect relations).

Inventory of regional ecosystem conditions. Inventory of conditions on public and private lands is essential to the collaborative management of regional and provincial ecosystems. Decisions on Federal lands affect decisions on non-Federal lands, and decisions on non-Federal lands affect decisions on Federal lands. Recognizing this interdependence can improve Federal land management.

Analyses of past actions. If future actions are carefully designed, high-quality information will be obtained to adjust subsequent actions, but this process will take many years. New information can be obtained quickly by analyzing past actions, but this information is usually of lesser quality than that obtained through designed actions. Retrospective studies are often limited by the lack of information about past actions, and they are limited to the range of past practices and natural events; they supplement, but do not replace, analysis of current and future actions.

Research that questions decisions. Research is needed to reassess scientific and\ managerial assumptions and societal views. Research is needed that asks scientific questions related to future needs: for example, if society wanted some condition in the future, what would be required to produce it? Direct feedback is needed to linked actions that allows for research to identify small-scale experiments and retrospective analyses overlooked in the decision process (fig. 2).

Integrating across watershed, provincial, and regional scales. Monitoring, research, and inventory should be consistent, comparable, and accessible across geographic scales. Common methods and quality standards are required to achieve integration between scales. The need for consistency should be balanced with the need for unconstrained feedback and the need to reflect inherent differences between sites.

Information synthesis

The proposed adaptive management system, in contrast to traditional management. will require more and better-synthesized information to make decisions; more information management to handle information generated through feedback mechanisms; and more tracking to improve the adaptive management system over time. This system, based on the principle that information is a vital resource, is consistent with the report of the Resource Information Working Group being prepared by the Regional Ecosystem Office. Activities within this grouping include:

Active Information management Managing information requires synthesizers who make information available in forms appropriate for multiple users, and translators who convert ideas into language that can be understood by a broad audience. To identify gaps in knowledge, feedback from the information-synthesis grouping to the adjustment and feedback groupings is required.

Consistent, compatible, and accessible databases and geographical information systems. Coordinating, among agencies, the approach to collecting, storing, and retrieving information is essential to reduce the cost of information, improve information quality, and ultimately improve decisions. Standards are needed to ensure that Information quality is maintained and improved. New mechanisms, such as electronic bulletin boards and terminals accessible to the public, are needed to ensure adequate access to agency information to facilitate scientist and public participation. Details are provided in the Resource Information Working Group report.

Synthesis of existing research information. Much valuable information exists in journal articles and other publications that is not widely known or used. Many managers are highly trained in specialized fields and may know little about other fields. Much of the specialized literature is often in a form not useful to managers because it is loaded with jargon and inadequately linked to other fields. Much information exists in national and international literature. Synthesis of existing information has seldom been rewarded in research institutions.

Mechanisms to accumulate and use local knowledge. People who live near and visit Federal lands know much about them. Acquiring and incorporating this knowledge into databases, knowledge bases, and decisions is essential.

Mechanisms to facilitate consensus-based expert analyses. The use of both local and scientific expert opinion has proved valuable in assembling perspectives on how various management strategies will affect selected fauna and flora that have been insufficiently studied (e.g., FEMAT 1993, Thomas et al. 1993). The scientific basis for objective collection and analysis of this type of data should be further studied to better understand the strengths and weaknesses of this approach.

Models and graphical tools to explore future possibilities. Managers, researchers, and the public will need to have access to computer facilities that are equipped with user-friendly graphical visualization systems, geographic information systems, simulation models, and on-line descriptions of ecosystem management principles. These tools will allow interactive, management-scenario development and analysis by those interested in exploring alternative management plans. Visualizing future possibilities and having a common understanding of terminology are necessary for learning about ecosystem principles and the tradeoffs between value statements and ecological capacity.

Decision-support systems for adaptive management Including a decision-support system with information synthesis is reasonable, even though information is gathered and used. and decisions requiring information are made throughout the adaptive management system. Research on learning and decision making, as well as modern technology and analytical methods, have made significant contributions to knowledge of natural and human systems. This understanding should be applied to addressing the legal, social, policy, physical, and biological aspects of decisions.

Cooler

National and international societal and scientific knowledge, laws, treaties (including tribal treaties), and conditions represent information resources and add complexity and constraints to the adaptive management system. Forests on Federal lands in the Pacific Northwest cannot be managed in isolation. Trends in human population growth, consumption of fossil fuel and other resources, and global environmental degradation will and should affect how forests are managed on Federal lands. The ramifications of changes in policy in the Northwest should be studied and included in, decisions. For example: Is reduced timber harvest on Federal lands in the Northwest shortening rotations on private lands or displacing harvests to other regions or countries? If the ultimate goal is human survival through protection global ecosystems, this broader view is essential.

Knowing about external information resources and understanding external constraints improve the adaptive management system by reducing courtroom feedback and political micromanagement, and by including important information gained under different conditions. Synthesis and communication of external resources and constraints is a major activity for the information-synthesis grouping.

Communication

The arrows that connect the system groupings (fig. 2) represent effective communication of information or sometimes specific instructions. Because communication between groupings is likely to be a bottleneck in the system, special efforts are needed to improve communication skills of individuals and agencies. Beyond the obvious needs for clear, two-way interactions, effective communication requires rapid feedback from the receiver to the sender on the form and value of the information. Improvements require training, as well as tracking and analyzing communication.

PART II. EXAMPLE APPLICATIONS

We present two hypothetical examples to illustrate how the adaptive management system could be used to learn to manage by managing to learn. These examples are purposely incomplete descriptions of some of the major steps that are needed.

Adapting Intermittent Stream Buffer Widths

One of the most significant additions in the President's Plan to the standards and guides is to reserve buffers along intermittent streams. This action limits harvesting and other activities on much of the land area in forests with steep slopes to protect stream and riparian habitat. Adapting these guides requires the following steps:

Step 1. Deciding on possible future adjustments

We begin with the assumption that the Record of Decision for the President's Plan will need to be adjusted because of feedback. Traditionally, managers would follow a set of regional guides until new plans were approved. The President's Plan differs by emphasizing the collection of information to inform future decisions. An important new step is to identify possible future decisions and the information needed to assess them.

Intermittent stream buffers, one of the more controversial decisions in the President's Plan, were set for key watersheds as 100 feet or a width equivalent to the height of one site-potential tree (average maximum height of dominant conifers in a given site), whichever is greater. The Record of Decision included these widths in all watersheds. Riparian buffers are thought to protect stream habitat structure and function; riparian habitat for obligate riparian species; riparian areas as refuge habitat; and connectivity of habitat for species that are not necessarily riparian dwellers but requiring the habitat to maintain interactions across populations. We assume that the decision integrates what people want with what is ecologically possible in the long term, and that ensuring protection of riparian function reflects what society wants.

The President's Plan will be implemented through subsequent decisions on the 12 provincial planning areas. Watershed analysis, which seems to us to belong in the information-synthesis grouping, must be completed before provincial decisions that differ from regional guides can be made. The decision makers remain the line officers of the various Federal agencies, as required by law. These line officers must coordinate with each other and use the provincial teams, scientists, and citizens to inform their management decisions.

An important part of this first provincial decision is to design management actions to produce the information to allow for possible adjustments during a second adjustment process. The plan to produce information must identify likely future adjustments and the information needed to make them. Specific criteria for triggering an adjustment would be identified for each potential adjustment.

Possible adjustments and the information needed to determine whether they are needed, might include:

Changing the width of the buffers In the regional plan. The evidence needed to determine if buffer widths are appropriate includes:

- Riparian function is degraded in watersheds with current buffers, and wider buffers are needed;
- Riparian function is not degraded in watersheds with current buffers, and no change is needed; or
- Riparian function is not degraded except with much smaller or no buffers, and a change is needed to allow other important activities in these areas.

Adding more site-specific information to regional guides. Evidence is needed to determine what factors, in addition to tree height, influence appropriate buffer width for specific sites, for example, slope, aspect, wildlife habitat requirements, and slope stability. Accumulated results from watershed analyses will help to determine what adjustments are needed.

Passing authority to set buffers to the provincial planning teams. If evidence is produced that suggests that Regional guides do not work well at smaller scales, then a decision to pass authority to the provinces might be warranted.

Guidelines for actions in the 12 provinces-required to evaluate potential adjustments-might identify the following minimum required elements:

- A control watershed with buffer widths for intermittent streams from the President's Plan;
- A comparable watershed with wider buffer widths (perhaps in an adjacent Late-Successional Reserve); and
- A watershed with many, small intermittent streams with a wider range of possible treatments, including one where intermittent stream buffers are removed entirely.[1]

Within broad guidelines, much would be left for the provincial planning team to develop. The number of treated watersheds might vary with province. Treatments on intermittent streams might include partial cuts and changed vegetation composition to look for ways to harvest trees without damaging streams or other riparian components. Restoration activities might also be tried in these buffers. The means that province teams might use to develop these treatments would also vary. Some teams may collaborate with local citizens familiar with the chosen watersheds or citizens committees that suggest alternative treatments in Adaptive Management Areas, after learning of the scientific assumptions behind the need for buffers.

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[1]Note that controversial treatments will not be applied to key watersheds or Late-Successional Reserves. Such treatments are likely to be concentrated in Adaptive Management Areas or, on a voluntary basis, on non-Federal lands.

On a voluntary basis, whole watersheds on adjacent private or State lands might have all intermittent buffers removed, for comparison. Through watershed analysis, fish and wildlife biologists and researchers from various agencies would be asked to identify the most important riparian variables to monitor. Citizens and social scientists might identify social variables that should be monitored. An interpretive trail might be planned through the various watershed treatments to allow access to the public. Specific outcomes of each action would be predicted and fully documented in advance. Outcomes that would convince people that the treatment failed would also be identified in advance.

If the political or judicial system decides this experimental approach is not tenable, an observational approach could be applied. Observational studies could be established by implementing the new buffer-width standard in drainages where it is feasible, and locating other comparable areas (possibly in collaboration with private land owners or in wilderness or reserve areas) where alternative conditions exist or can be created. Differences in these alternative conditions must be large enough that changes in habitat, biodiversity, and fish and wildlife dynamics can be detected. Depending on available habitat and the goals of managers, scientists, and the public, measurement plots can be installed and monitored over time to evaluate changes in habitat conditions and fish and wildlife response. This approach provides less power for detecting differences between the new buffer-width standard and other alternatives than would the experimental approach. The risk of confounding effects and introducing statistical bias is higher in a study of this type than In more formally designed experiments.

A third alternative is to implement the buffer-width standard throughout the landscape and monitor habitat condition, biodiversity indices, and fish and wildlife response over time. This approach will not provide much useful information and will restrict the ability of managers to adapt. This approach is described by Hilborn (1992) as "passive learning" and by Walters and Holling (1990) as a "passive adaptive process." Walters and Holling also state that this approach is "likely to confound management and environmental effects." and that opportunities for improvement might be missed if people are blinded by the assumption that the implemented approach is the optimal one. They also state, however, that passive approaches do sometimes provide valuable information not easily obtained by other means.

A combination of these approaches is likely to be more powerful than a single approach. Other linked actions would include research to evaluate whether applying the buffer-width standard or other biological or physical factors best explain the observed changes in riparian habitat and riparian-dependent species, and retrospective research to compare and contrast effects of past management.

The plan would be reviewed by the regional research and monitoring committee, managers, scientists, and the public.

Step 2. Producing information for future adjustments

Managers and researchers, and possibly the public, collaborate in implementing a plan for linked actions. This plan. developed as part of the adjustment process. includes both managerial and scientific activities: large-scale management experiments, medium to small-scale formal scientific experiments, and retrospective studies. These experiments and studies are nested in such a way that: large scale activities will provide experience with complex regional and provincial scale responses; activities at scales such as watersheds will help to interpret large-scale responses and provide experience at medium scales; and small-scale activities will help to interpret larger-scale responses, evaluate a wider range of possibilities, and test ecological theory. Each activity scale is related to and interpretable at both larger and smaller scales. These activities should also be linked in such a way that ecological and social processes that either influence or are influenced by these activities can be studied over time.

Step 3. Soliciting feedback

Management actions would be monitored, with oversight from cooperating scientists and citizens. Citizens might be hired to assist with taking measurements. Regional monitoring would include a check to see that acquired data would be adequate for a regional assessment. Analysis of effects would be ongoing. Initial indications that a watershed was being negatively affected by a treatment might precipitate a quick adjustment to prevent undesirable effects. Research agencies might conduct separate studies that look at even broader possible management treatments, treatment assumptions, and retrospective analyses. A social and economic assessment on the effects of various buffer widths and alternative management strategies is needed to determine the effect on local and national economies, as well as indirect influences on private lands. Monitoring these watersheds might form the backbone of a regional inventory system that also includes non-Federal lands. All information would feed into the information-synthesis grouping.

Step 4. Synthesizing information

Information from all sources would be assembled and synthesized to focus on the potential adjustments identified in step one, along with newly developed potential adjustments. New issues may arise unexpectedly from observations of management effects, retrospective studies, new legislation, public surveys, and experiences in other regions. Data would be accessible to managers and researchers working at regional, provincial, and local scales. Visualization programs might be developed that explore how changes in buffers are predicted to affect ecosystem processes and functions through time.

Step5. Adjusting again

An adjustment may or may not be warranted, depending on the outcome of the management actions and their evaluation, and other information and issues that have appeared since the first adjustment, especially information collected in watershed analysis. A decision not to adjust might be based on insufficient information, and monitoring would be continued. Entirely new issues may arise that make the management comparisons less relevant. Judgment must be used to decide when to eliminate or stop monitoring comparisons, recognizing that a long-term commitment is often needed to yield relevant information.

A second entry into a regional adjustment substitutes for a second Forest Conference and FEMAT process. For example, a new regional buffer policy might be adopted. Whatever the result, the problem of appropriate intermittent stream buffer widths is not likely to be fully resolved. The new policy would be evaluated in a series of new watershed comparisons and other actions in the provinces, repeating steps 1-4.

Adapting the 50-11-40 Concept

The following hypothetical example is based on and closely follows the adaptive management guidelines for the 50-11-40 rule included in the Final Draft Recovery Plan for the northern spotted owl (USD11992). The 50-11-40 rule was developed to provide for dispersal of northern spotted owls among Habitat Conservation Areas, the precursors of the Late Successional Reserves. Although the rule was not adopted as a standard in the ROD (1994) for the President's Plan, it is still being used in watershed analysis as a basis for determining the quality of dispersal habitat. Therefore, discussion of adaptive management of the 50-11-40 concept is still pertinent. New guidance oh dispersal habitat that could result from adaptive management would be used implementing the Plan locally, and might play a role in periodic revisions of the Plan.

Step 1. Deciding on possible future adjustments

As in the previous example, we assume that the 50-11-40 concept will need to be adjusted because of feedback and that management must produce the information needed to determine what needs adjusting and how the adjustment will be made. The Plan calls for "retention of adequate habitat conditions for dispersal" of spotted owls among Late-Successional Reserves. Guidance from the Plan called for managing Federal forest lands within the range of the northern spotted owl so that 50 percent of the land in each quarter township under each Federal agency's jurisdiction will be dominated by trees at least 11 inches in diameter at breast height with at least 40-percent canopy cover (the "50-11-40 rule"). This concept is based on a combination of scientific research, professional judgment, assumptions of owl sustainability, and cartographic convenience. The Plan suggested that the first step in adjusting the concept should be a thorough understanding of the assumptions it is based on, and developing working hypotheses of how the concept would function to achieve objectives.

These hypotheses could then be tested to determine the efficacy of the 50-11-40 concept. Factors that could be tested could include availability and density of prey, foraging success, adult and juvenile owl survival rates, and the demographics of owl populations. These factors could be tested both in landscapes that meet the 50-11-40 concept and in landscapes managed under alternative concepts. A formal experimental approach would provide the highest quality information to managers, scientists, and society for evaluating the efficacy of the concept (Irwin and Wigley 1993).

If the political or judicial system decides that an experimental approach is not tenable, an observational approach could be applied. Observational studies could be established by implementing the 50-11-40 concept on lands where it is feasible, and locating other comparable areas (possibly in collaboration with private land owners or in wilderness or reserve areas) where alternative conditions exist or can be created. Differences in these alternative conditions must be large enough that changes in prey and owl dynamics can be detected. Depending on available habitat and the goals of managers, scientists, and the public, measurement plots can be installed and monitored over time to determine habitat conditions and owl response. This approach provides less power for detecting differences between the 50-11-40 concept and other alternatives than would the experimental approach. The risk of introducing statistical bias and of confounding effects is higher in a study of this type than in more formally designed experiments.

A third alternative is to implement the 50-11-40 concept throughout the landscape and monitor habitat condition and owl response over time. This approach will provide minimal information and will restrict management's adaptive ability. The limits to this approach are described in the first example.

A combination of these approaches is likely to be more powerful than a single approach. Other linked actions would include research to evaluate whether applying the 50-11-40 concept or other biological or physical factors best explain the observed changes in owl populations.

Outcomes that might be expected if the 50-11-40 concept is inadequate guidance. adequate guidance, or unnecessarily restrictive guidance would be:

- Unstable or declining populations on landscapes that meet the 50-11-40 concept (indicating that the 50-11-40 concept is not sufficient to sustain a stable population);
- Higher survival rates for individual owls. maintained or increased body mass of individual owls, and stabilized or increasing populations of owls under 50-11-40 conditions than under other conditions (indicating that the 50-11-40 concept is sufficient to sustain a stable population); or
- Stabilized or increasing populations on landscapes that do not meet the 50-11-40 concept (indicating that the 50-11-40 concept may be more restrictive than necessary to sustain a stable population).

If the 50-11-40 concept does not perform as expected, changes can be made to: (1) the guide for the proportion of the land on which the diameter and cover requirements apply, (2) the diameter or cover guides, (3) the guide that the concept must apply to each quarter township. (4) the guide that the concept be applied across the entire landscape, (5) the guide that the 50-11-40 concept be applied to lands under each Federal agency's jurisdiction separately, or (6) some combination of these guides. Alternatively, the guideline could be changed in more fundamental ways; for example, corridors of high-quality habitat could replace the existing guidance.

Managers, scientists, and society must also be aware that spotted owl behavior and habitat condition probably vary by province. This variation suggests that standards and guidelines be tested and refined within provinces and areas with significantly different ecological conditions.

Managers, scientists, and the public must know when review of the effects of alternative standards and guides is appropriate and what, if any, action is necessary to refine these standards and guides to provide more-appropriate management guidance. Standards and guides should be reviewed either when regularly scheduled or when information collected as part of the adaptive management process or new information from other sources indicates review is needed.

As in the previous example, this adaptive management process would be reviewed by the regional research and monitoring committee, managers, scientists, and the public.

Step 2. Producing information for future adjustments

Managers implement the plan for linked actions on the ground with collaboration from scientists and possibly the public (refer to the first example).

Step 3. Soliciting feedback

The information necessary to evaluate the efficacy of the standards and guides will come from monitoring the conditions where the 50-11-40 concept is being evaluated. Six kinds of effects should be monitored: (1) the effects of the alternative standards and guides on habitat; (2) the effects of alternatives on management activities; (3) the effects of the alternatives on northern spotted owl prey and predators; (4) the effects of these alternatives on owl behavior and survival; (5) the effects of these alternatives on economic and other social factors at the local, regional, and national scales; and (6) the effects of these alternatives on private lands. Related research projects will also be initiated to further determine owl behavior-particularly as related to alternative management practices-and potential management activities used to provide owl habitat.

Step 4. Synthesizing information

When a review of the standards and guides is deemed appropriate, information from all sources should be evaluated to determine if, and to what extent, adjustment is necessary. After all information is analyzed, and alternative standards and guides evaluated, managers, in collaboration with scientists and the public, must decide if the accumulated evidence is sufficient to justify selecting one of the alternative sets of standards and guides in one or more provinces. Formal experiments on the alternative standards and guides as described above has the advantage of providing managers and scientists with strong evidence for what should be altered and to what extent. The other means of collecting information can also help with these decisions, but not to the extent that formal experiments can. Managers, scientists. and the public will use available expertise, knowledge, and decision-support systems to aid in this decision process.

Step 5. Adjusting again

After a decision has been made whether to modify the standards and guides, future decisions will be required to continue the adaptive management process. If the decision is to adjust, adaptive management must be applied to this modified set of standards and guides. This process will include cycling through the adaptive management system testing the continued efficacy of these new standards and guides. If an adjustment was not made. further monitoring or research may be necessary or a decision may be made to forgo further information-gathering on this issue. Either way, input from managers, scientists, and the public should be included.

New issues, such as the interbreeding of barred and spotted owls, may arise that confound the effects of the 50-11-40 concept and the comparisons of alternatives with this concept. Other issues may override the 50-11-40 concept, such as adoption of new habitat guidelines for anadromous fish. These scenarios are also candidates for adaptive management, and strategies should be developed to apply the adaptive management process to them as well.

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A Systematic approach to adaptive management is proposed to simultaneously manage at the regional, provincial, and watershed scales and to reorganize the activity of agencies to better support the concept of adaptive management. Reorganizing management activities into these four groupings is recommended: adjustment (expanded decision-making); linked, not single actions; feedback, including monitoring; and information synthesis. A major new focus for the collaborative decision process is to identify and set priorities among possible future adjustments. Linked actions that integrate managmenet and research would then be designed to produce the information needed to decide whether to make proposed adjustments. Feedback and information synthesis will follow to facilitate and inform future decisions. The strategy requires making better decisions; improving public participation; and developing science-based management.

Keywords: Adaptive management, feedback, adjustment, future decision, linked actions, management experiments, information synthesis, decision support, science-based managment, public participation, the lacing model.

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