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Ecosystem Restoration: A Manager's Perspective

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Key questions addressed in this chapter

- *Concepts which underlie design and implementation of restoration action*
- *Relevant considerations when making restoration decisions*
- *Options and techniques that have been applied in restoration efforts*
- *Application of restoration concepts, options and techniques in four different types of settings*
- *Characteristics common to successful restoration efforts*

Keywords: Rehabilitation, reclamation, wetlands, arid lands, riparian areas, degraded lands

Ecosystem management, at root, is an invitation, a call to restorative action. (Ed Grumbine, 1994)

The significant problems we face today cannot be solved at the same level of thinking we were at when we created them. (Albert Einstein)

1 INTRODUCTION

Elements of ecological restoration underlie much of what we think of as ecosystem management, and restoration projects on federal lands represent some of the most exciting, challenging, and convincing demonstrations of applied ecosystem management. The Society for Ecological Restoration defined restoration as "the process of reestablishing to the extent possible the structure, function and integrity of indigenous ecosystems and the sustaining habitats that they provide" (Clewell and Covington 1995). Most managers have limited interest in distinctions between restoration and rehabilitation, reclamation, maintenance, or prevention of degradation. Managers focus on problem-solving where current conditions limit ecosystem functions, treating restoration as a broad array of possible actions, which include rehabilitation and reclamation. As a result, a variety of reference conditions is used to define the direction restoration efforts take.

Restoration is a subject of considerable breadth. Restoration projects are occurring across the country, on all types of federal land (in mixed ownerships, as well), and at scales ranging from local habitats to watersheds, landscapes, and bioregions. The level and scope of activities has increased dramatically in the last 10 years, but federal agency involvement in ecological restoration is not new. It is evolving. Restoration has been, and continues to be, a vital part of federal land management.

Integrated actions organized around ecological processes and functions underlie an increasing number of agency efforts to restore, improve or maintain natural resource conditions. Emphasis on ecosystem function requires integrating multiple perspectives and addressing complex physical, biological, social and economic interactions. Additional complexity is added by the scale at which issues like species recovery are addressed and by the accelerating pace of change. Examples of species recovery issues affecting large-scale landscapes include high profile species such as salmon, wolves, northern spotted owls, marbled murrelets, and red-cockaded woodpeckers.

Although much has already been described, understanding the relationships within ecological communities is constantly being improved. As more is learned, new biological and physical linkages are highlighted, thus requiring more study. But land managers must continue to make decisions about the design and direction of activities on public lands in the context of a constantly developing body of knowledge. It is a continuous effort to balance what is known, what could be studied, and what can be done, with the goal of improving ecosystem functions. Baseline data about ecological functions, studies of comparable situations and opportunities for experimentation are all necessary considerations in developing practical solutions. But effective solutions must also consider project-specific factors such as cost, risks, conservation values, potential effects, stakeholder interests and landownership patterns.

The purpose of this chapter is to provide a practical reference for land managers to aid decision-making and spur innovation and experimentation in the field of ecological restoration. Numerous restoration efforts were reviewed to develop an overview of successful projects, barriers to positive results, and promising possibilities. Cross-cutting concepts such as historical context and restoration decision factors are presented first. Then, to illustrate current practices and experience four scenarios are presented:

- Decline in terrestrial systems or conditions
- Impaired stream or riparian function
- Impaired wetland function
- Lands with few biological legacies

Scenarios were used, rather than selected case studies alone, in order to broaden the treatment of applied restoration. These four scenarios were selected based on their broad applicability and importance in public land settings. This chapter represents a search for common approaches and useful findings. It is not a scientific or a perfectly representative sample of all restoration activities or scenarios. Case studies and scenarios are used to illustrate ongoing restoration activity and applied concepts.

1.2 Overview of Ecosystem Restoration Approaches

Ecosystem restoration is an exercise in complex problem-solving with an emphasis on the processes and functions of the system. Although restoration goals and objectives are generally based on site conditions, management actions are necessarily designed around land uses or interventions. Potential restoration actions can be grouped into three different types of approaches: structural treatments, management of land uses, and biological intervention. Each approach represents a group of techniques, but the different approaches are frequently combined. For example, grazing use is frequently modified to correspond to prescribed

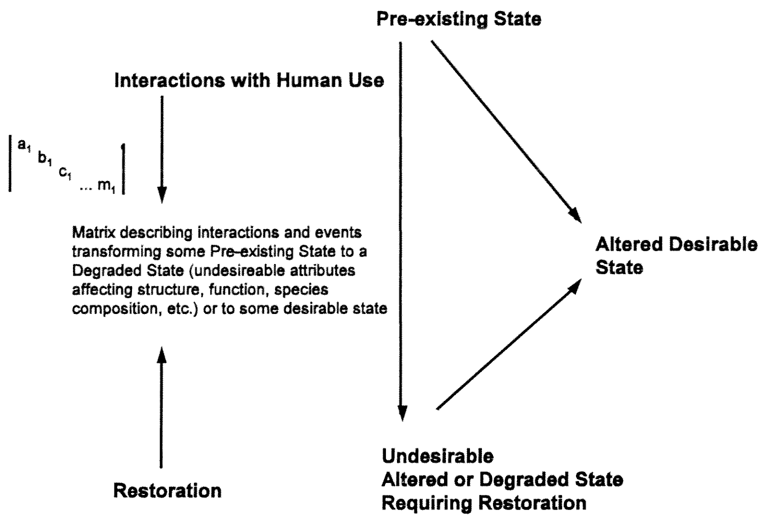

Fig. 1. Conceptual model illustrating the relationships between human use and restoration strategies (modified from Dyer and Ishwaran 1992).

fire activities, seeding, and plant responses. The approaches are based on the type of management action and discussed separately to improve the clarity of the review.

The structural approach includes modification of the physical attributes of the system, or their arrangement and distribution, toward a more desirable state. Examples would be log and rock placements in streams to restore aquatic habitat diversity or introduction of prescribed fire to change plant community structure.

The land use approach modifies the distribution, timing, intensity or duration of uses affecting the landscape. Examples would be changes in domestic livestock grazing or timber practices in sensitive riparian habitats.

The biological intervention approach changes the species composition of an ecosystem, controlling undesirable species or introducing and promoting desirable ones. Examples would be controlling leafy spurge in native grasslands or reintroducing wolves.

The three different approaches are common components of restoration projects, occurring in a wide variety of settings and combinations. Although none of the approaches is applied entirely in isolation, one frequently dominates. Each of the approaches is discussed below in the context of different settings, or scenarios, listed above.

The factors that caused, or are causing, degradation often provide insight into the approach to take for restoration. The factors may include current or past: infrastructure (such as drainage ditches, dikes, dams, levees, roads, culverts, bridges), land uses (grazing, mining, timber harvest, residential or industrial development, hunting, fishing, camping, boating), land-use practices (how and when the land uses are conducted) or management practices (such as fire suppression).

Ecosystems exist at a variety of levels of productivity, integrity, sustainability, and resilience. Although some may be in a relatively undisturbed condition, others require some degree of restoration to improve the functions of ecological processes. If some pre-existing state (a reference condition) is subjected to a complex array of interactions with humans over an extended period of time, some change would be expected. Figure 1 provides a simplified conceptual model highlighting the complex interactions (the matrix) between human uses and ecosystems that have affected all landscapes to some degree. Restoration attempts to affect the interactions and move the system toward a desired set of conditions, often referenced (1) to the range of states that historically occurred on the site or (2) to thresholds between acceptable and unacceptable ecological function. Restoration does not duplicate the pre-existing state (Eddleman 1997).

1.2 Historical Overview of Ecological Restoration

Problem-solving with the intent to restore structure and function to ecological systems has a long history. Most of the early efforts were based on trial and error (Odum 1972, Covington et al. this volume). Odum cited the work of George Perkins Marsh in 1864 analyzing the causes of decline in ancient civilizations as one of the first "ecosystematic" views of human interaction with nature. That perspective was developing in a parallel fashion in essays in German, English and Russian through the later 19th century (Odum 1972).

By the 20th century, two general approaches provided most of the foundation for both ecological study and restoration. The first, a holistic approach, focuses on whole systems and works with processes, functions and results. In 1972, Odum illustrated the holistic ecosystem concept as a "black box" with its inputs and outputs. From a manager's perspective in 1997, inputs might include land uses and disturbances acting on an ecosystem. Outputs might include the characteristics and trends in the system, observed through monitoring. The holistic approach acknowledges that the complexity, number, and dynamic nature of interactions and components in an ecosystem prevent complete description of entire systems and all their components.

The holistic approach seeks to understand the dynamics of processes, functions, interactions, and relationships for the purpose of determining how the "black box" will respond. A holistic approach to restoration tends to focus on what might improve characteristics of the "black box" (e.g., ecological site, community, watershed, province), expecting individual species to benefit or react in their own way.

The second approach is more component-based and attempts to decipher and understand specific relationships and interactions among each of the key components of the ecosystem. This commonly leads to more finite studies of individual species or other system components, as they are presented with the array land uses and disturbances represented in an ecosystem at any given time. The component approach seeks to understand the parts and then try "to build up the whole from them" (Forbes from Odum 1972). A component-based approach to restoration tends to focus on improving an individual population, expecting the system to be healthier if the identified population responds favorably.

Although the holistic approach emphasizes physical and community processes, functions, and attributes, as a foundation for species, the component approach (starting with parts of an ecosystem) is more individual-species-oriented and treats ecosystems as a composite of individual parts. Friction between proponents of the different perspectives continues. But managers are likely to argue that neither needs to be universally applied to the exclusion of the other. In fact, a holistic approach provides an excellent framework for applying and interpreting component-based information, particularly on larger scale restoration issues and problems.

Humans have been managing a relationship with land for centuries. In the last century, the recognition of a need to restore and maintain ecosystems was most commonly embodied in preservation strategies such as the establishment of parks, preserves, and reserves (MacCleery 1994). Although this strategy has value and is still applied (e.g., new wilderness areas under the Wilderness Act of 1964), it obviously cannot be applied everywhere. Land uses continue in parks and preserves. Parks and preserves do not occur in isolation from their surroundings and they generally include some lands where ecological functions are impaired. Thus, even parks and preserves need ecological restoration. It was inevitable that concepts would emerge to manage land uses and apply treatments to sustain or restore the health of lands and waters.

Ecological restoration corresponds closely to what Odum called "applied ecology." Applied ecology, as a biological and physical science, probably has no definitive beginning. But if tracked prior to the 1960s, it largely consisted of managing the components of the ecosystem (Odum 1972). Where the objective was more deer, something was changed on the deer winter range, and deer were counted to measure the results. If the concern was flooding or erosion, a structure would be built to control it. Some efforts resulted in a restoration of some improved ecological function or component (even if the objectives were not focused on the ecosystem as a whole). Successful species recoveries in the 20th century include whitetail deer, elk, wild turkey, and pronghorn antelope.

But the results of some problem-solving attempts were not as positive. Some streams were channelized that were meant to meander. Some forests were pruned and manicured, reducing their biological diversity. Fire was suppressed and exotic species were introduced into native rangelands, often with good intentions to produce forage or stabilize streambanks. It should be no surprise that projects designed with narrow objectives or with a limited appreciation for ecosystem complexity could have unintended consequences.

By the 1970s, natural resource management became more integrated and holistic with the advent of interdisciplinary teams to analyze land uses, management actions and impacts, propelled in part by requirements of the National Environmental Policy Act (see also MacCleery and LeMaster, this volume for overview of natural resource management history). By the 1990s, this need for increased integration of perspectives and expertise, using partnerships to develop and test solutions to complex ecological problems, is well recognized. But one agency with considerable biological expertise related to individual species may not have experience in implementing management actions or integrating them, in a sustainable way, with the social and economic systems that are affected.

Many state and federal agencies have missions oriented around individual land uses or selected ecosystem components (fisheries, fish and wildlife, forestry, recreation, agriculture, economic development). Even within agencies with a more complete cross-section of experts and perspectives, individual "programs" are centered around single components of the ecosystem. This same potential for polarity is mirrored in public discussion of natural resource management. The result is sometimes a complex array of competing positions, objectives, and perspectives that retard or block attempts at restoration action (Apfelbaum and Chapman 1994).

Thus, the shift to ecosystem management and restoration is in its infancy. To implement or improve implementation of ecosystem approaches on federally managed public land, the Interagency Ecosystem Management Task Force (1995) listed 31 recommendations for improvements in federal agency coordination, partnership, communication with the public, resource allocation and management, the role of science, and information and data management.

Yet the reasons for restoration can be persuasive: aesthetics, benefits to humans and the health of the systems themselves (Apfelbaum and Chapman 1994). In many respects, progress in restoration hinges on our abilities to learn and understand, to align multiple interests and needs with improving ecosystem health, and to gain agreement on how to begin to act.

2 RESTORATION DESIGN

Successful ecosystem restoration efforts take a landscape perspective, gather and assess adequate information, set clear goals and objectives, and monitor to assess results.

2.1 Landscape Perspective

A landscape or regional perspective is essential for effective restoration of ecosystem functions (Eddleman 1997, Apfelbaum and Chapman 1994). The reason is obvious. Plant-animal communities in an ecosystem are interlinked and ecosystems are dynamic (Eddleman 1997). Examples include: (1) fire is an important disturbance regime affecting vegetation type, distribution and condition over large areas; (2) soil types, water occurrence, and topography vary, affecting vegetation and wildlife movement; and (3) many fish and wildlife species range over a large area utilizing a variety of habitats and habitat conditions at various times during the year (see also Concannon et al., Gosz et al., this volume).

Ecological classifications and regional data sets provide the framework for understanding disturbances, plant communities, species occurrence, flow events, stream channel types, and susceptibility to erosion (see Grossman et al., and Carpenter et al., this volume). Regional information can then be organized to provide context and integration for restoration goals and objectives across large landscapes. Regional goals and objectives, in turn, create a management direction that can be stepped down to meet both local and regional needs using more site-specific knowledge (Interior Columbia Basin Ecosystem Management Project, Draft EIS, Appendix 3-1). Actions for some species-specific restoration efforts can be very locally focused. For example, actions related to a rare plant species may be applicable only to very specific soil, elevation, aspect, and plant community characteristics. But even then, the larger-scale review contributes to understanding habitat relationships.

The technical tools available to assess ecosystems at the landscape scale include techniques for ecological site inventory and classification. These are generally well-developed for the major federal land management agencies, although tools to better integrate data at larger scales are still developing. Efforts have been initiated to develop national and international classification systems (Eddleman 1997). A number of classification, inventory and monitoring methods have been compiled and summarized by the National Research Council (1994).

Assessing conditions, trends, opportunities, and risks at a regional level is difficult. Quigley et al. (1996) identified some valuable lessons related to regional assessments based on their experience on the Science team for the Interior Columbia Basin Ecosystem Management Project:

- Science needs to provide the types of information that answer questions that can improve decisions, recognizing politics and budget are deciding factors in implementation.
- Involved scientists must be integrative and comfortable with broad policy issues and concerns, rather than functional.
- Better balance is needed among timelines, data quantity and quality, and emerging decision issues. Timely information has more impact than presenting detailed data later.
- Goals must be identified early.
- More cause and effect data are needed, rather than just descriptive material.

Much information and experience exists for restoration. In some cases, generally available sources of information, in combination with existing site data, may be enough for analysis of local needs. In other cases, sources would also need to include local publications and contacts to describe adequately local conditions and experiences, thereby improving the probability of success. Models that simulate landscape changes can be useful analytical tools to relate complex sets of data, but they have limitations related to scale, assumptions used, data quality, and number of simulations (Johnson et al. 1996).

In response to landscape level issues, many recent restoration projects have expanded from localized action to consider strategies, effects, and relationships at a watershed scale. For example, high sediment loads on the Bad River in South Dakota affect ice buildups, dam release capacity, electrical generation, and fishing success for 20 to 30 miles along the Missouri River. Addressing bare ground, accelerated erosion, and poor infiltration along Bad River has the potential to reduce the average sediment production of 1,418 tons per square mile (Platts 1990). The linkage between streams and management of the surrounding uplands is illustrated by the level of sediment transport into the riparian zone (Moore and Flaherty 1996), the role riparian areas play in plant dispersal and wildlife movement (Gregory et al. 1991), and the relationship of activities and conditions in the watershed to hydrologic regimes (Barrett et al. 1991).

Disturbance factors, ecological resiliency, and the suite of ecological processes necessary for ecosystem functions all affect strategies for restoration. Success is generally tied to compatibility of the restoration projects or strategies with the complex interactions of soils, vegetation and water, often at a watershed scale (Eddleman 1997). To understand the physical, chemical, and biological attributes of a site or system practitioners in restoration must also have the ability to analyze diverse sets of data (Hunter 1991).

2.2 Setting Goals and Objectives

Setting restoration goals and objectives often leads to a debate over what results should be expected, and how fast they should come. Most successful projects sampled focused on improving trends in the physical, chemical and biological attributes of a site or system. Goals and objectives are often expressed in terms of desired conditions or trends. The conditions selected are intended to gauge improvement in ecological function.

Determining desired conditions and trends is a critical challenge for restoration. The U.S. and Canadian National Park Services routinely target "pre-Columbian settlement" (pre-European) conditions as their restoration objective. Other agencies and organizations target conditions and processes that fall within a range of variability (natural, historic or "reference"), or they aim simply to improve certain conditions or control invasive species and release "natives." The second approach recognizes that variations in ecological conditions are normal and focuses more closely on ecological functions and capacity than on conditions at a point in time. Improvement, a positive direction in the trend, is then generally assessed against reference conditions.

Reference conditions can be estimated in various ways by examining similar areas considered "pristine"; by searching out historical records (Hindley 1996); by examining soil and plant relationships and patterns; by examining the fossil record for the area; by examining adjacent vegetation for signs of flooding and fire; or by talking with local residents who may have some historical knowledge of the area or by relating conditions at multiple sites to a level of ecological function (see also Covington et al. this volume).

Objectives are usually based on practical considerations. What is the distribution of existing conditions across the landscape? How much of a given landscape can be reasonably treated to restore desired conditions over a reasonable length of time? What effects, if any, will such treatments have on existing human uses, jobs, and quality of life? On the Ouachita National Forest, for example, open stands of shortleaf pine and prairie grasses and forbs potentially could cover one million acres of public land. The management plan, however, establishes a pragmatic objective to treat about one-tenth of the area, recognizing both the challenge of sharply increasing prescribed burning and public uncertainty about the proposed changes. As managers and citizens work through these issues, the restoration objective may need to be adjusted (USDA Forest Service 1994, Henderson and Hendrick 1991).

It is possible to set unrealistic or overly rigid restoration objectives. Human ability to predict or control many factors that affect rates of recovery (e.g., precipitation from year to year) is limited. Sometimes the drive to force the rate of ecosystem change by prescribing rigid standards or objectives diverts attention from sustainable solutions that might allow human uses to coexist with properly functioning ecosystems. For example, a preoccupation with the presence, absence or amount of use can undermine creative techniques that focus on timing or methods.

2.3 Planning, Assessment, and Evaluation

Planning provides the analytical framework for restoration. It develops alternatives, specifies actions, identifies necessary resources, sets monitoring to provide feedback on effects, and plans for maintaining or adapting in the future. Planning, assessment, and evaluation processes generally draw from the same funding source as implementation for restoration actions across a large area. With limited funds, the cost of these processes affects the level and rate of restoration action. The tradeoff is between (1) the level of knowledge these processes create to abate risk, build support, and add value to restoration designs and (2) their cost, length, and complexity. Planning, assessment, and evaluation are necessary to making informed decisions, but time and effort for these analysis processes must be balanced with restoration action.

Restoration efforts must assess conditions and options with an interdisciplinary team that includes landowners, a variety of specialists, and members from interested organizations. A team facilitates consideration of multiple viewpoints, sources of expertise, and resource values from the start. Participants and proponents then take some responsibility for the outcome. If the team functions well, multiple perspectives and expertise will be integrated in development of the proposed solution. However, care should be taken to evaluate sources of information and expertise the team uses for any inherent biases or other limitations. It is important to distinguish underlying values from facts (Adams and Hairston 1994).

The processes of assessment and evaluation draw on research and monitoring to characterize conditions and trends, so management actions can be adjusted. Although pre- and post-project monitoring is essential to evaluate success (Hunter 1991), it is sometimes desirable to combine a project with research studies to incorporate more complex questions at the watershed, riparian corridor, and community scales (Chambers 1994). Site selection for research should reflect (1) common occurrence (for broad applicability), (2) ability to compare different responses, (3) potential to exhibit varying recovery potentials, (4) community composition and structure, and (5) system or species vulnerability (modified from Chambers 1994, Crow et al. 1994). It may also be relevant to consider research when the information could be broadly useful (Manning et al 1984, rooting characteristics of meadow species), or where restoration of some species has been difficult or inconsistent (Matisse 1994, bitterbrush).

Data collection on each project cannot meet standards for evaluation by research scientists because of cost. Where research is not appropriate or justified, some level of monitoring is necessary. But everything cannot be monitored to the same level without draining valuable resources from the effort to take restoration actions across large landscapes. The translation from ideal to realistic requires tradeoffs concerning when, where, and what types of planning, research, and monitoring are appropriate (see Fig. 2). A sampling

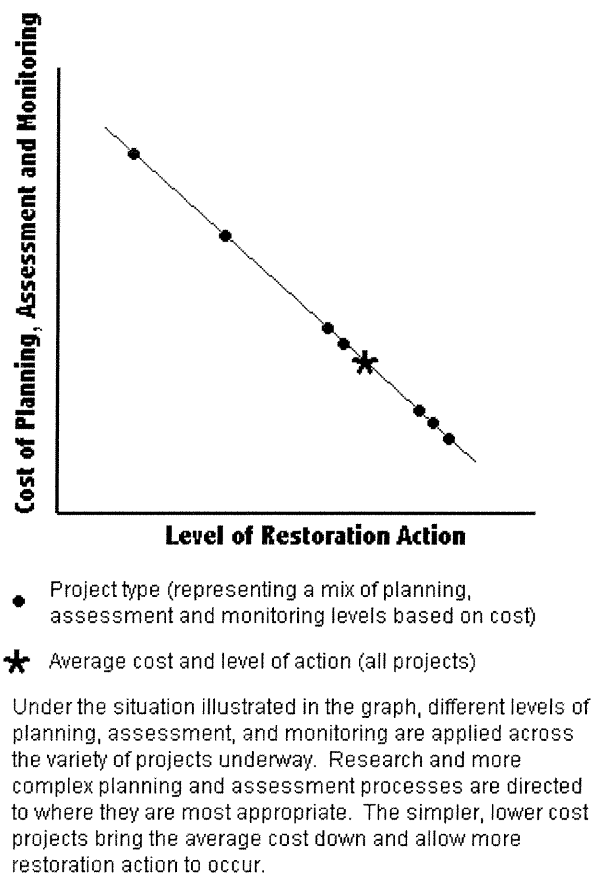

Fig. 2. Conceptual relationships between planning, research, monitoring, and implementation under a constant level of available funding for projects across a landscape.

of multiple projects that are similar may be one option to stretch monitoring funds. Monitoring priorities may also be affected by whether the project is well supported by literature and experience, or by the values at risk, at either the project or regional level.

With the practical limitations on data gathering, maintenance, use, and application, it is essential to use data effectively (Callaham 1990, Crow et al. 1994). In many cases, it may be most effective to direct the restoration action and data gathering toward experimentation (adaptive management). An adaptive management approach requires recognizing a project may not be successful. With risk must come commitment to an incremental approach that allows mid-course corrections (Hunter 1991). Restoration through adaptive management must continue because it is the most fertile area for rapid innovation.

Factors that will almost certainly influence a restoration plan are what is technically, physically, and economically possible, as well as what is socially acceptable. Technical solutions or the physical means to carry them out are not usually the primary problem.

But economics are almost always a significant factor in restoration design. Depending on the size of the effort, costs can be astronomical. For example, restoring the 250-acre Ballona wetland (near Los Angeles airport) is expected to cost $50 million, in part because a road through the marsh would have to be elevated to restore tidal flows (National Research Council 1992).

3 DECISION FACTORS FOR RESTORATION

While a systematic approach aids in assessing reference conditions, current conditions, and restoration alternatives, it is perhaps even more essential for the decision selecting restoration actions and monitoring strategies. Restoration decisions involve choices about when, where, and how to commit scarce amounts of time, effort, and money. Checklists based on Cairns (1983) and Apfelbaum and Chapman (1994) are included as Appendix A as an aid. This review of restoration projects suggests that, when making restoration decisions, considerations should include level of ecological function, cost-effectiveness, conservation value, potential effects, relationship to other actions and trends, and risk management. However, none of these factors should be considered separately.

3.1 Existing Level of Ecological Functions

Although an understanding of conditions is necessary, actively restoring ecosystem health requires focusing primarily on processes and functions, not on conditions (Quigley et al. 1996, Eddleman 1997). Conditions, particularly at broad scales, can be highly variable (Quigley et al. 1996). Many systems have also been altered by human settlement (or other factors) to a degree that options to achieve pre-settlement conditions are not practical.

The level of ecological functions is important because it provides insights into: (1) necessary investments to restore ecological processes, (2) possible responses to restoration measures, and (3) the priority the restoration project should receive. In some cases, systems are altered to a point that a substantial investment of time, effort, and money would be necessary, time effort and money that could be better used in other locations (Pyke and Borman 1993). Conversely, restoration action in systems that are functioning, but at risk of significant decline, could prevent decline for a modest investment.

3.2 Potential Effects

A basic consideration is where to work first. In most cases, recovery begins at the top of the watershed (Platts 1990). Watershed scale analysis has been useful to direct restoration projects, provided it is simple and adaptive (Natural Resources Law Center 1996). It is often advantageous to consider the current balance of successional stages represented and give high priority to restoring those which are underrepresented, rather than focusing on some historical stage. Watershed function and vegetative structure (distribution, arrangement) are also frequently key factors. A simple annual review of projects can provide the basis for evaluating potential effects when setting work priorities.

Following Odum's concepts of ecological "outputs," potential effects relate closely to the level of ecological functions. The impact of a restoration investment where a system is at risk of decline can be significantly greater than where a system is already improving or has declined to the point of being non-functional. Natural events or other management actions may be necessary to stabilize a non-functional system before any significant restoration occurs. Increments of restoration can occur in slow, steady increments every year, or may tie closely to climatic cycles or events occurring at longer intervals (see Fig. 3).

Potential effects also relate closely to how directly restoration action addresses the causes of system decline and limiting factors to recovery. Restoration will be ineffective if the causes of degradation are allowed to continue, regardless of the physical or biological investments into the system (i.e., treat the cause, not the symptoms).

The cumulative effects of activities within a watershed are the result of actions on all the ownerships (Reiter and Beschta 1995). Thus, landownership patterns and participation are factors in the expected results. Developing a technically "right" approach to restoration, without the cooperation necessary to implement improvements across ownerships, accomplishes little. Lack of landowner support has prevented or delayed riparian improvement in several cases reviewed by Platts (1990).

Potential effects are not just biological, chemical, or physical. Economic effects are also playing an increasing role in restoration. Domestic livestock grazing is one example where economic outputs and ecological results can be compatible. Improved management practices can yield benefits such as increases in the quantity and quality of forage, increased animal production, control of poisonous plants, increased water yield, control of soil loss, and reduced conflict (Johnson 1992). U.S. Government Accounting Office (USGAO 1988) noted an "...increasing number of ranchers are coming to accept the benefits healthy riparian areas provide their ranching operations." Successful efforts consider both the ranching operation and the bio-

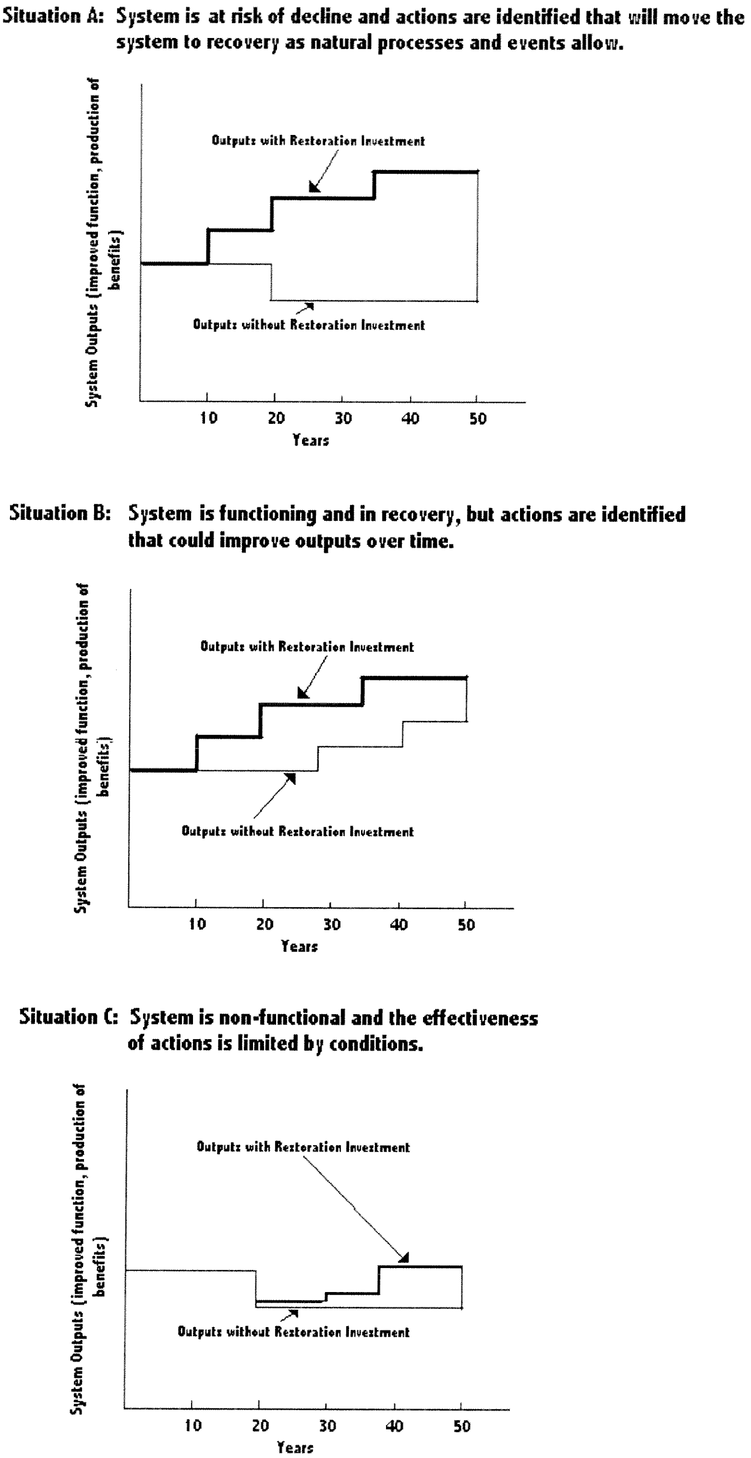

Fig. 3. Comparative ecosystem outputs in three situations, with and without restoration investment over time.

logical/physical factors using an interdisciplinary approach, with wildlife, fisheries, hydrology, range conservation, and soils specialists (USGAO 1988). Riparian objectives clearly can be attained in many cases without loss of livestock forage, diet quality, or weight gain (Moore and Flaherty 1996).

Economic benefits can also be related to other uses, such as recreational fishing or reservoir water quality. Recreation user purchases of licenses, tackle, gas, and food support local communities (Hunter 1991). Even more generally, the public at large benefits when 118,000 cubic feet of sediment are kept out of a reservoir downstream of Sheep Creek in Montana (USGAO 1988).

3.3 Risk Assessment

Risk assessment is an a analysis of the likelihood of negative outcomes from various management options, including both action and inaction (see Haynes and Cleaves, Volume III). It can include loss or decline in a species or community. Adams and Hairston (1994) illustrated the tradeoff as shown in Fig. 4.

Risk must be managed at different levels and scales, particularly if flexibility to respond to local conditions and needs is to be retained (Haynes et al. 1996). Assessments at regional scales require "averaging" across a broad array of site conditions (ibid). Some averaging is necessary to assess regional conditions and trends to provide an overall regional direction. For example, assessing and managing risks to a threatened or endangered species that requires broad connectivity (e.g., salmon) must consider conditions and land uses across at least a basin.

Most risk issues have implications at each of the regional, subregional, landscape, and site scales (Haynes et al. 1996). For example, assessing fuel loading in relationship to wildlife habitats at the regional level might lead to a very different conclusion than at a site or landscape level (T.M. Quigley, personal communication). It is not that either assessment is more correct, or more necessary. They simply represent the issue at different scales and both are relevant to decisions.

3.4 Conservation Values

Regardless of the degree of degradation a system exhibits, restoration frequently is the best strategy to integrate the multiple ecological, economic, cultural, and social values people place on a particular ecosystem or landscape. But values placed on ecosystem attributes in a diverse society are variable. Some species, communities, or ecological functions may be valued more highly because of their rarity, sensitivity, social role, or economic importance. When the ascribed values are high and shared by a group (e.g., key ecosystem components to ecologists, deer to hunters, salmon to Northwest Indian Tribes, or watershed function in a municipal watershed), the level of action and the priority for action may be greater (MacCleery and LeMaster, this volume).

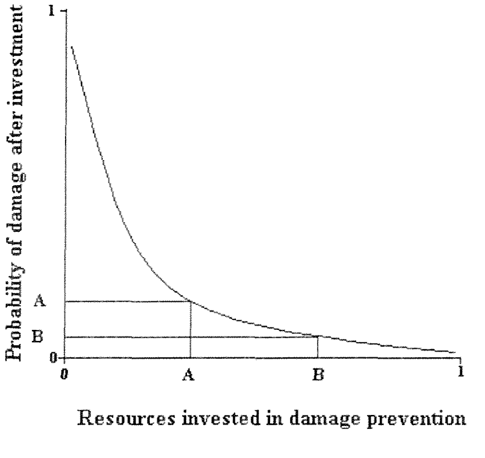

Fig. 4. Examples of Risk Assessment. Note that investment A reduces probable damage about 80 percent but twice the investment, case B, further reduces probable damage only a small amount.

Conservation values assign importance to protection of critical species and ecosystems by evaluating the representation and condition of all vegetation types under some kind of conservation strategy (Burley 1988). But they also have social and economic dimensions that are essential to implementing and sustaining restoration projects. The social and economic values integrate such human needs as wood fiber, food (agriculture, animal forage), road access, and recreation (Interagency Ecosystem Management Task Force 1995, cf. Daily et al. 1997).

Trust in a restoration project develops with sufficiently broad consensus among affected communities of interest, including the scientists, conservationists, and landowners. However, some people may have difficulty visualizing the improvement that is possible, arguing solely on philosophical concepts of what is "natural" or who is "right." For success, all those involved must agree that objective information about the restoration project and its potential effects provide a better basis for dialogue than individual positions. Any party can initiate a vision for restoration, but the intent of the dialogue must be to identify common goals, with acceptable consequences (Interagency Ecosystem Management Task Force 1995).

Some confusion about the complex relationships between proposed restoration actions and a constantly changing landscape is probably inevitable. But neither objective proof of degradation nor assignment of blame for current conditions are necessary prerequisites for restoration action. Success is often promoted by fostering basic understanding of proper functioning condition, disturbance regimes and patch dynamics when explaining or advocating restoration objectives.

Working groups with diverse representation are common, and potentially powerful, tools used to facilitate the necessary communication and understanding (see Yaffee, Volume III). Yet even when diverse interests commit to work together to solve problems, events sometimes occur that break any trust which develops (Natural Resources Law Center 1996). Success requires establishing, and constantly re-establishing, open communication, willingness to change, and willingness to deal with side agendas (Callaham 1990).

Many current working groups are watershed issue forums promoting restoration through communication, education, and conferences (Natural Resources Law Center 1996). At least partially as a result, increasing numbers of restoration projects involve multiple cooperators. The involvement of multiple agencies in Resource Advisory Councils and Provincial Advisory Committees in the West (recently including the Dakotas) in this kind of public dialogue is certainly a promising development. In Oregon, recent federal legislation has recognized public/private partnerships for restoration in two basins.

Odum (1997) suggested that restoration is most successful when four key groups work together in a coordinated manner. These include citizens groups, governmental agencies (local, state, and federal), scientists, and business interests. He also suggested that if any of the groups is not strongly involved, restoration projects may not achieve their goals.

Controversy, even though it can be a barrier to restoration action, sometimes brings restoration issues into public focus. Recent examples include the spotted owl, cutthroat trout, bull trout and anadromous fish issues in the West. Even the perceived risk of a lawsuit or controversy may sometimes affect restoration strategies or promote change (Platts 1990). For example, corridor fencing in a riparian area can be more acceptable to a rancher if it facilitates a "no effect" determination under Section 7 of the Threatened and Endangered Species Act (Munhall 1996). Although progress has been made, much could yet be done to align incentives and management processes to promote consensus on conservation values (Western Governors' Association 1997).

3.5 Relationship to Other Actions and Trends

No restoration project can be considered in isolation from the land uses, management projects or resource trends around it (Eddleman 1997). For example, implementing a structural restoration action (check dams, for example) without correcting land uses that are also contributing causes is unlikely to be successful over the long term. Elmore and Kaufman (1994) provide a good conceptual model relating the human caused stresses and natural stresses to the stability and resiliency of a system (as seen in Fig. 5).

Although the model in Fig. 5 was developed for riparian systems, the concepts apply to restoration in all systems. Systems which are under high levels of natural stress (e.g., a steep stream with highly erodible banks and high flows) can be pushed into decline by moderate levels of human use. Conversely, systems which are stable and resilient can tolerate properly

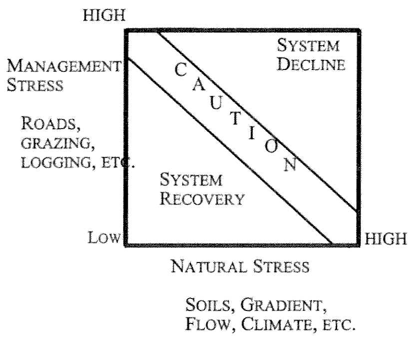

Fig. 5. Stress and stability in ecosystems.

managed human use while continuing to recover. In all cases, restoration action must consider other uses and trends.

Continued monitoring may also identify new limiting factors that require modifications (Hunter 1991). But in natural systems, results are not always immediate, so frequent changes in management strategies may not be appropriate.

3.6 Cost-Effectiveness

Assessing cost-effectiveness relates all of the other factors to cost. The intent is to spend where and when the funding will yield the best results or the most benefits. The effectiveness of the same level expenditure varies depending on what it does, where it takes place and the timing of the action (see Fig. 6).

Potential for Results

HIGH RESULTS/LOW COST	HIGH RESULTS/HIGH COST
Simpler actions Consensus to implement Success in similar applications Frequently at smaller scales Planning costs are low More actions with similar funds Monitoring may be simpler	More complex actions Consensus must be obtained More uncertainty of outcomes Frequently involve larger scales Planning costs are higher Fewer actions with similar funds Monitoring more costly
LOW RESULTS System is not ready to respond to the restoration action Causes and limiting factors are incorrectly diagnosed Costs to assess, plan or monitor are out of balance with action Implementation does not meet expectations Lack of consensus prevents or retards necessary action Objectives are set with inadequate or inaccurate information (can be good data but at the wrong scale)	

Cost to Assess, Plan, Implement and Monitor

Fig. 6. Samples of how cost effectiveness can integrate other decision factors with cost.

Cost and the frequency of intervention or maintenance are also constraints requiring consideration. For example, neutralizing acidic inputs to the Cranberry River in West Virginia requires trips over snow once a week in the winter using 4×4 trucks or snowmobiles at a cost of $80,000 per year (Hunter 1991). These recurring costs must then be weighed against the benefits from the project and the other restoration opportunities foregone to fund the effort. Although not every case involves costs of this magnitude, many do involve the need for constant maintenance to ensure structures function properly or fences are maintained (Hunter 1991).

4 APPROACHES TO TREATING TERRESTRIAL SYSTEMS AT RISK

Scenario: Whole ecosystems have been altered, affecting the representation and sustainability of plant and animal communities within a region or landscape.

Terrestrial ecosystems are distinct communities of plants, wildlife, insects, and other organisms present in various regions. As presented by Berger (1988), terrestrial systems can include agricultural lands, barrens, coastal areas, prairies, rangelands, and temperate forests. This chapter focuses on terrestrial systems not converted for agricultural use. Terrestrial ecosystems of concern include those most commonly occurring on federally administered public lands such as forests, drylands, prairies and rangelands.

Recognition of the landscape changes that have occurred during the 19th and 20th centuries have heightened concern over the need for ecosystem restoration in the 1990s. Broad interpretations of current conditions fuel concerns over:

- Radical change in fire-maintained ecosystems,
- Invasive plants and animals reducing biodiversity, and
- Widespread habitat change.

As mentioned above, restoration requires clear goals. The Buck Creek Serpentine Woodland Restoration project of the National Forests in North Carolina provides a good example. The restoration goals set for this project include: (1) maintain a physiognomic complex of forest, woodland, and grass-dominated areas while increasing the woodland community coverage to 50 percent of the landscape; (2) reduce frequency of trees greater than 25 cm (diameter at breast height) by 50 percent and trees 2.5–25 cm by 30 percent; (3) reduce shrub coverage by 25–50 percent, resulting in at least 50 percent of the acreage having shrub cover less than 15 percent and increasing the coverage of grasses and forbs; and (4) reduce accumulated leaf/grass litter by 30 percent (Simon, personal communication).

4.1 Management Options for Terrestrial Restoration

For this scenario, the options for restoration of terrestrial systems are grouped into the three different approaches discussed above: structural treatments, management of land uses, and biological intervention.

4.1.1 Structural Treatments

One alternative to restoring large scale systems is to alter the structure and composition of the vegetation. Often structural changes in terrestrial systems are achieved by reintroducing processes such as fire. Changes in vegetation structure are important to spatial relationships and physical processes. But structure also directly affects wildlife species abundance and diversity because most wildlife respond more to structure than to species composition (Elmore 1984, Puchy and Marshall 1993).

Some of the most ambitious restoration projects on federal lands are those focusing on re-establishing fire as a key ecosystem process. Examples include efforts to restore longleaf pine-wiregrass, ponderosa pine, quaking aspen, shortleaf pine-bluestem, tallgrass–midgrass–shortgrass prairies, Midwestern oak savannas, and many other once prominent ecosystems (see Case Study 1). In some cases, these efforts dovetail with or complement efforts to increase the future representation of old growth; in others, the efforts are independent.

Upland systems in which fire is to be restored typically represented major elements in pre-suppression landscape on the order of hundreds of thousands to millions of hectares. Restoration work in these systems usually is not a matter of renewing previously existing conditions on a hectare-by-hectare or highly site-specific basis, but more one of re-establishing components of a shifting vegetation mosaic. Partial exceptions to the rule are those cases where restoration objectives are highly site specific, such as for some Midwestern glades. An implicit understanding in either case is that the landscape vegetation mosaic was and remains dynamic, i.e., that the structure and composition of landscape elements shift in space and over time. A good illustration comes from the Midwest Oak Ecosystem Recovery Plan (Leach and Ross 1995: 48):

> "Historically some sites may have cycled between nearly closed oak woodland to very open oak savannah and back again, depending on stochastic fluctuations in fire frequency and intensity and other factors. Recovery efforts should not 'freeze the vegetation in time'..."

Case Study 1. Simpson Township Barrens, Illinois

This case study summarizes restoration work designed to reestablish Midwestern glades and oak woodlands on the Shawnee National Forest. Cutting and prescribed burning have been used successfully to restore these communities on approximately 235 acres.

Geographic Area/Location

The Simpson Township Barrens occupy about 235 acres within the Shawnee National Forest in southern Illinois (Johnson County).

Participants

Illinois Department of Natural Resources, Illinois Chapter of The Nature Conservancy, Illinois Nature Preserves Commission, Johnson County Boy Scout Troop, Johnson County Highway Department, and Shawnee National Forest. Some work was accomplished by inmates of the Illinois Department of Corrections.

Restoration Goals

Although many restorationists set a goal of reestablishing pre-European settlement conditions, too little information was available to set such a goal in this case. Instead, Shawnee National Forest managers planned to restore the site to something approximating the 1930s landscape, which could then be easily maintained by occasional prescribed fires. Original surveyor section line notes, contemporary literature, and 1938 aerial photos provided a framework upon which to base strategies. Additionally, remnants of plant communities containing plant species characteristic of natural forest openings gave insight concerning species and conditions that may have been present in the 1930s.

Background

In the late 1970s, the Illinois Natural Area Inventory recognized the 69-acre "Simpson Township Prairie" as having a significant feature, a "Grade A Limestone Glade" community. The Shawnee National Forest officially designated this site as a Natural Area in its 1986 Land and Resource Management Plan. A review of 1938 aerial photographs revealed that what is today forest was once open oak-hickory woodland and limestone glade; succession, in the absence of fire, has led to gradual loss of the more open conditions. Field visits confirmed that the natural communities of the site were threatened by canopy closure, which suppresses the shade-intolerant plant species. These species were surviving in dense shade as scattered, non-flowering rosettes or etiolated individuals. Occasional "wolf" trees, once open grown, displayed shade-pruning from encroaching woody competition.

Restoration prescriptions were first designed to include a 5-acre management area, then 112 acres and finally 235 acres, a size that allowed for a more comprehensive landscape approach. Managers decided that aggressive work was needed on the portion of the barrens that included the two limestone glade communities. In the winter of 1987–88, six cords of firewood were cut from the glades, restoring more open conditions on approximately five acres. The management area was unequally divided by a roadway, which enabled the site to be treated as two separate units, an east side and a west side, with relative ease. The glades were burned in the spring of 1988 for microsite management.

A landscape burn was implemented the spring of 1989 for both units, and this activity revealed a west-side glade that had been previously overlooked; at this point only 87 acres had been burned on the west side and 25 acres on the east. Since the initial landscape burn, each side has been prescribed burned on a rotational basis to ensure that both sides are never burned during the same season within a given year. Fall burns are conducted when possible and individual units are left unburned for 2 to 3 years depending on the unit's management needs. Since a prescription update in 1994, the Shawnee is managing 106 acres on the east side of the roadway and 129 acres on the west, and the prescription has included additional tree girdling and removal as needed. The west side contains three sizable glades as well as several smaller openings. Prescribed burning is now the main form of management. Fire is allowed to interact with the landscape, resulting in a mosaic of burned and unburned areas within the units providing refugia for insects and other animals. Management prescriptions are updated every 5 years based on results of monitoring and ecological research.

Results

Glade conditions have been restored on 10+ acres and open woodland now covers much of the remainder of the site. Several conservative and rare plant species on the Illinois state list of threatened and endangered species have emerged. One sedge appears to be an undescribed species. Several species of butterflies and other insects are attracted to the diversity of flowering plants, which now includes more than 200 native species. The glade on the east-side has become a stop for wildflower and birding enthusiasts.

Exotic plant species are still present in the managed areas, most notably Japanese honeysuckle and white and yellow sweet clovers. While fire seems to temporarily reduce the cover of these species, total eradication has not occurred. Another challenge is that as the dry upland woods have become more open due to management, they have become attractive to users of all terrain vehicles (ATVs). The ATV riders have made some rudimentary trails through the woods as well as using an abandoned wagon trail and burn lines. A third problem encountered was that the ring fire patterns used initially to burn the two glade areas resulted in nearly complete ignition, with little if any unburned areas for plants and animals left. The current landscape burning approach allows for mosaics of burned and unburned portions and provides dispersal corridors or linkages between isolated barrens remnants.

Restoration of Simpson Township Barrens became the model for natural area management across the Shawnee National Forest. Managers have learned not to be afraid to take an aggressive approach in the initial stages of restoration. Despite earlier reluctance to cut and burn areas, the Shawnee has learned to work closely with other agencies, institutions, conservation groups, and individuals in preparing and implementing restoration prescriptions.

Contact Persons

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Designing effective restoration of fire regimes requires objective information about the likely effects of fire on vegetation, wildlife, and soil, water, and air quality, especially when fire remains a solely destructive force in the minds of many. In keeping with the experimental nature of restoration, fire influence need not, and probably should not, be restored on every acre where it may have played a role historically.

Focusing attention on as little as 10 percent of the total potential restoration area may be appropriate where information about fire effects is tentative and/or logistic considerations limit what can be achieved. Restoring 50 percent or more of the total potential area may be appropriate where supporting data is substantial. One offshoot of landscape-scale planning is that some managers are now experimenting with burning larger areas than they may have previously considered. This option is showing promise, not only for expanding how much prescribed burning can be accomplished but also for significant cost savings. Costs per acre for prescribed burning tend to be inversely proportional to the size of the area burned.

Frequency and seasonality of fires are important factors, and lack of attention to these variables can produce unintended results (Parker 1990). Dormant season fires in the Southeast, for example, often induce coppicing in oaks. Systems in which fire has been excluded for decades will, in all likelihood, have fuel loads, root reserves, stand structures, and regeneration dynamics far different from those in which fire remained a force. Restoration, therefore, is not just a matter of reintroducing fire, but of designing and adapting for a whole suite of variables.

In some cases fires have become more frequent with site conversion. In portions of Idaho, Oregon, and Nevada, large areas have been converted to cheat grass, an exotic annual. Cheat grass is very susceptible to fire when it cures and it thrives with frequent fires. Strategies to break the cycle of frequent fire have included strategically interspersing 30- to 400-foot wide "green strips" of fire resistant species such as crested wheatgrass. This is sometimes combined with planting of native species such as sagebrush to begin to reestablish diversity and structure (USDI NBS 1994). Results have been mixed, perhaps due to drought. But at least two instances have occurred where green strips have stopped fires from advancing (USDI NBS 1994).

Vegetation community structure and composition can be treated directly by techniques such as thinning and brush crushing to affect fire occurrence (frequency, intensity, effects) or to improve watershed health and habitat diversity. The combined use of fire and thinning to reestablish or accelerate the return of more open forest and grassland conditions, or of old-growth characteristics, is on the rise. Covington et al. (this volume) provides an example in the ponderosa pine forest of the Southwest. Other examples include shortleaf pine ecosystems in the Ouachita Mountains (USDA Forest Service 1994) and pinyon–juniper in the Southwest (e.g., Carrizo Demonstration Area, Lincoln National Forest; Alexander, undated publication) (see Case Study 2). Promising attempts at North American grassland restoration are summarized by Allen (1988) and Berger (1990).

Desertification is another restoration problem which is frequently treated using structural techniques. Desertification has been defined as the climatic dryness induced by human disturbances of the topsoil and natural plant communities (United Nations 1977). In many cases, desertification has been caused by improper grazing, introduction of non-native flora and fauna, or destruction of habitat by development. Desertification is a process where the land becomes denuded, with the land smoothing and sealing over. Water infiltration is impeded, as is air transfer from the soil.

Techniques used to restore desert areas by reversing the desertification have been developed and discussed (Dixon 1990; Clary and Johnson 1983). Imprintation is a mechanical process used to roughen and open the desert soil to infiltration by air and water. With imprintation, revegetation is improved during the seed establishment and germination phases (Dixon 1987). In addition, runoff and erosion are reduced through imprinting. Dixon (1990) indicated imprinting with native perennial grasses has been quite successful on several sites. The treatment was also responsible for crowding out tumbleweed and burroweed.

4.1.2 Managing Land Uses

In many cases, land uses have caused landscape modifications that affect the structure and function of ecosystems. Many temperate forest ecosystems in North America have been modified by conventional forest management practices. Industrial forest practices, specifically even-aged management for timber production, have created forests comprised of single species with little or no understory present (Horowitz 1990).

Elimination or restriction of land uses is a management option to consider as part of a restoration project, if only to establish baseline areas for comparison with more actively managed portions of restoration areas. Dramatic change, sometimes accompanying an agency designation that restricts or eliminate land uses, may be the only option to achieve restoration in some cases. The most formal Congressional designations — Wilderness, National Wild and Scenic Rivers, National Recreation Areas — are also sometimes paired with

Case Study 2. Restoration of a Southwestern woodland ecosystem Carrizo Demonstration Area, New Mexico

This case study summarizes efforts to restore damaged watersheds in the pinyon–juniper woodlands of the Lincoln National Forest. The Carrizo Demonstration Area was established in large part at the urging of local landowners and grazing permittees. Their continued support, together with several active partnerships, has been critical. Over 5,000 acres have been successfully treated since 1989, but thousands more remain in degraded condition.

Geographic Area/Location
The Carrizo Demonstration Area is located on the Smokey Bear Ranger District of the Lincoln National Forest in south-central New Mexico. It encompasses 55,000 acres and includes both National Forest and private lands.

Participants
USDA Forest Service, New Mexico Department of Game and Fish, New Mexico Division of Forestry and Resource Conservation, New Mexico State University and NMSU Cooperative Extension Service, New Mexico Range Improvement Task Force, thirteen grazing permittees and three private landowners.

Restoration Goals
Stop active accelerated soil erosion, stabilize steep gully slopes, and restore permanent riparian vegetation. Goals also include providing for a variety of wildlife habitat, increasing plant and animal diversity, and restoring the natural beauty of the landscape.

Background
The Carrizo Demonstration Area was established in 1989 as a pilot effort in watershed restoration. Much of the Carrizo area reflects a history of intensive grazing pressure and fire suppression, which resulted in reduced grass production, increased soil erosion, and proliferation of pinyon pine and juniper trees. Records show that in 1902, 80,000 head of livestock were grazing on what is now the Smokey Bear Ranger District.

The grazing capacity today is about 5,000 head, and pinyon and juniper form a nearly continuous canopy in many places. As tree canopies closed in, grasses and forbs that held soil in place and provided forage continually declined. The extensive gully system that developed helped send silt-laden water into streams and rivers. Many of the area's perennial streams and springs declined in flow.

The impetus for the restoration project came from private landowners and grazing permittees in the area. Both had to contend for years with the deposition of millions of tons of sediment that originated on National Forest land. Grazing permittees were concerned about steady declines in livestock grazing capacity. Wildlife interests also have a stake in the degraded Carrizo area, pointing to the adverse effects on habitat for deer, elk, wild turkey, songbirds, and many other species.

Using the USDA Forest Service's Southwestern Region Terrestrial Ecosystem Survey (a mapping system that combines soil type, potential natural vegetation and climate), the Carrizo area interdisciplinary planning team identified high priority areas for treatment as those with unsatisfactory watershed condition and high soil productivity. Of the 18 map units included in the Terrestrial Ecosystem Survey (ranging in size from 1,345 to 6,284 acres), only half were rated "satisfactory." Prescriptions, with detailed descriptions of desired future condition, were prepared for each map unit. Treatments employed include reseeding, prescribed fire, thinning, and gully reshaping. Many were undertaken as partnerships. (See also USDA Forest Service, Southwest Region (1995).)

Results/Outcomes
More than 3,200 acres identified as being in unsatisfactory watershed condition have been treated to increase herbaceous ground cover. Four miles of gullies have received structural improvements or sideslope stabilization treatments, and five miles of roads have been eliminated. More than 1,000 acres have been treated with prescribed fire. Where treatments have been implemented, watershed conditions have improved dramatically. Cool season native grasses and forbs thought to have vanished have now returned in abundance. Springs have begun to flow again in some drainages.

Except under extreme conditions, using prescribed fire to open up areas of pinyon-juniper is very difficult, if not impossible. It is therefore necessary to thin extensively in many areas. Progress toward restoration goals is slower than many stakeholders would prefer.

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restrictions on land use. For example, passive restoration of some forms of old growth is probably taking place on millions of acres of federally designated wilderness, recreation, and special interest areas where commodity production has been eliminated.

Although some would argue that only "nature" can restore old growth, others point out that North American ecosystems are so altered that merely eliminating one activity or another is not likely to lead to restoration (see Bonnicksen et al., this volume). What may in fact develop are ecosystems that never existed before (Botkin 1990). Some federal land managers and conservationists have concluded that several once common community types or system states are unlikely to be restored without active intervention. Management decisions concerning how harvest of forest products occurs affect restoration of forest structure and function. Recent approaches increase emphasis on diversity and the preservation of essential ecological conditions and functions over timber and other commodity production values. "New Forestry" (Franklin 1990) was an early move toward ecosystem management that intertwines commodity production with maintenance of ecological diversity. Timber harvest, however, cannot completely substitute for, or simulate, ecosystem disturbances and processes such as fire. In fact, it can create its own distinct effects through mechanical disturbance (Johnson et al. 1996).

Puleo (1990) discussed techniques used at the H.J. Andrews Experimental Forest in Oregon when actively managing for "New Forestry." These techniques included a strong emphasis on "green tree" retention during any type of harvest. Leaving coarse woody debris on site after any harvest-based treatment was also incorporated. Finally, stand treatment no longer emphasized clearcut-based silvicultural techniques. Instead foresters began prescribing partial harvests, such as shelterwood or seedtree regeneration harvests to mitigate visual concerns and improve structural diversity in the residual stand (see Box 1).

Recently, the Forest Service and the Bureau of Land Management used regional planning and assessment in the Forest Ecosystem Management Assessment Team (FEMAT) report in 1993 to set a regional restoration direction. The report built on the New Forestry movement, evaluating ten options for managing federal forest lands within the range of the northern spotted owl in the Pacific Northwest. Option 9, selected for implementation, focuses on increasing late successional seral stages and maintaining biological diversity through both management activities and natural events such as fire. It promoted broad scale restoration and led to several management process innovations.

Since approval of the Northwest Forest Plan in 1994, the federal agencies in the Pacific Northwest have been striving to restore old-growth conditions over areas ranging from mixed conifer to single-species plantation forests. The predominant methods for managing young forests at the early- or mid-seral stage are partial harvests (such as thinnings) or controlled fire events (prescribed burning). Ecosystem management in forests in the Pacific Northwest is still new, and evidence of success at these early stages is not clearly documented (Covington et al., this volume).

The Interior Columbia Basin Ecosystem Management Project represents the next generation of regional ecosystem planning in the Northwest. It also addresses managing uses on public lands, building on concepts developed for the Northwest Forest Plan. But the Columbia Basin Project covers 72 million acres of public lands in a 144 million acre area spread primarily across eastern Oregon, eastern Washington, Idaho and Montana. In addition to covering an area about the size of France, the project also added innovation for regional assessment and planning (Interior Columbia Basin Ecosystem Management Project 1997) (see Box 2).

Box 1
Options for Restoration Forestry

1. Managing the land for older forest by preserving existing old growth and other late successional stands, allowing second growth stands to mature, and placing managed stands on longer rotations;
2. Retaining structural diversity, including snags and downed logs, in managed stands;
3. Retaining and restoring large, intact stretches of forest unfragmented by roads, clearcuts and other openings;
4. Retaining and restoring corridors and other linkages between forests;
5. Allowing natural fires to burn, using prescribed fire, or applying silvicultural manipulations that simulate fire and other disturbances in order to maintain a full spectrum of seral stages and structures;
6. Stopping road construction and reconstruction, and obliterating and revegetating most existing roads; and
7. Recovering viable populations of rare species and reintroducing extirpated species.

Noss and Cooperrider (1994)

The scientifically based regional approaches in the Pacific Northwest identified aquatic conditions of streams and watersheds, effects of roads, alterations in composition and structure ecosystems, changes in disturbance regimes (especially fire), exotic species invasion and community resiliency as major considerations for future management action (Quigley and Arbelbide 1997, Quigley et al. 1996). These concerns are related to settlement, population growth and land use practices. They have implications for diverse ecosystem conditions including available plant and animal habitat, water quality, air quality and human quality of life. Our review of case studies found those same concerns, causes and implications to be widespread across the United States. So are the efforts to address them.

One study in the Pacific Northwest, designed to evaluate active management treatments in forested systems, is the Demonstration of Ecosystem Management Options or DEMO. Four treatment options to restore stands to mature-to-late seral stages more rapidly than without treatment (passive management) are being evaluated. Stand treatments are delineated based on the extent of removal and the dispersal pattern used. Harvest removals range from 15 to 40 percent. The study is a collaborative effort designed to evaluate effects on a broad array of variables including forest wildlife, invertebrates, and understory biota. The study is currently in the pre-treatment data collection phase, with data collection and analysis expected to

Box 2
Process Lessons and Innovations for Regional Assessments and Planning in the Pacific Northwest

Northwest Forest Plan (FEMAT)

- amendment of land use allocations and management plans across a regional landscape,
- establishment of strategies to address late successional forest, aquatic conservation and the survey and management of habitat for a wide diversity of species,
- creation of a watershed analysis process,
- creation of advisory committees at the regional and province (generally basins) levels to advise the land management agencies on implementation, and
- creation of a Regional Ecosystems Office to coordinate and facilitate plan interpretation and application among the many affected or involved agencies and offices.

Interior Columbia Basin Ecosystem Management Project (ICBEMP)

- a restoration, rather than reserve, strategy can be the basis for the preferred alternative,
- replacement of interim strategies for fish habitat and late successional forest management,
- a very deliberate focus on ecosystems rather than a species-by-species approach,
- inclusion of both forest and range lands,
- improved integration of social and economic issues and information,
- concepts and models that may improve the flexibility, local applicability and cost efficiency of assessment processes and management prescriptions,
- development of separate processes for scientific assessment and land management planning with deliberate ties between the two,
- increased consultation with counties, states, federal agencies, American Indian tribes during development and analysis of alternatives, and
- a very open public participation process during development of the scientific assessment and land management alternatives.

continue for at least the next decade.

Forest product companies with extensive land holdings in western Oregon and Washington are also modifying private land forest management to comply with federal requirements for wildlife habitat protection and maintenance. One company, Plum Creek Timber Company, has established a Habitat Conservation Plan for 170,000 acres of their privately owned timberlands (Jirsa 1995). The plan emphasizes ecosystem restoration and maintenance at the landscape level, rather than single species restoration. It is currently under public review and revisions are expected before implementation occurs.

In forests of the Southwest and the interior of Oregon and Washington, forest health issues drive most restoration efforts. Covington (1994) noted that disruption of natural fire regimes has occurred across the inland West and in the Southwest since European settlers first appeared and began to control wildfires. O'Laughlin (1994) discussed extreme forest health problems on several national forests in Idaho, using net growth to mortality ratios as indicators of the severity of these health problems.

A twofold strategy for forest health improvement was outlined by O'Laughlin. First, restore the dominant species best suited for the sites of concern, such as ponderosa pine, western larch, and western white pine. Second, prevent unhealthy conditions from occurring, primarily through reductions in stand density through thinning operations. This approach emphasizes restoring forest habitat, without concerns over specific forest-based wildlife species. Another alternative is to design actions to promote the presence of a desirable wildlife species. The species is assumed to represent the health of the ecosystem, and successful restoration is then measured by how the species responds.

In Eastern deciduous forests, efforts to restore forest areas to pre-European settlement conditions have been less intensive, primarily because of the fragmented landownership patterns. In addition, past efforts to manipulate conditions in these stands through thinning and prescribed fire have generally failed. However, these methods may still be the most useful techniques for restoring eastern forest ecosystems if used properly.

Forest restoration efforts are increasing in the South as well. Best known are the longleaf-wiregrass, sand pine, and shortleaf pine-bluestem restoration projects. But public land managers and scientists in this region are also experimenting with "new forestry" practices (Baker 1994). The Ouachita and Ozark-St. Francis National Forests have been testing alternative stand level treatments and large scale ecosystem management strategies since 1990. On the Ouachita National Forest, natural reproduction has replaced clearcutting and planting. Uneven aged, modified shelterwood and seed tree systems are used to achieve desired landscape conditions and mixed stands of pines and hardwoods are maintained (USDA Forest Service 1994).

Generally, restoration of forest ecosystems to some desired or needed condition is being either studied or tested on many forests in the western United States. The techniques vary slightly but common methods used include (1) harvest-based treatments to affect stand density, species composition or stand structure, (2) retention of woody debris and/or snags, and (3) use of controlled fire.

The need to increase biodiversity is now commonly integrated into forest health treatments. "Non-managed" areas, where catastrophic disturbances like the 1988 fires in Yellowstone National Park are allowed to occur without intervention, are not common. As a result, forest health treatments in Western forests are increasingly oriented toward active intervention to maintain or restore ecosystem functions and conditions.

At a general level, the options for restoration on rangelands are similar to those for forested systems. However, there can be differences related to their geographic position in most watersheds, their relationship to settlement areas and private lands (agriculture, residential, etc), their land use history and, sometimes, their more open vegetative character or gentler terrain (see Box 3).

As illustrated in Case Studies 1 and 2, restoration of grasslands is also related to fire disturbances and the abundance of woody species. In the Northwest, the encroachment of woody species in rangelands is a primary restoration concern (Quigley et al. 1996).

Vegetation community structure and composition are also a concern in non-forest vegetation types because most wildlife species respond most readily to structure (Maser et al. 1984). The Bureau of Land Management and Forest Service worked with ranchers and interest groups to adjust rangeland management on 250,000 acres in central Oregon to address declines in sage grouse populations, as well as other wildlife and vegetation concerns. Techniques included prescribed burning and changing the timing, duration, and frequency of livestock grazing to improve nesting cover and increase the forb component in the plant community. The intent is that improvement in long-term management of sagebrush communities will allow for potential increases in sage grouse populations, as well as other plant and animal species. There have been some indications of a positive response in sage grouse numbers, although long-term trends cannot yet be established and influences by climate are known to be a factor (USDI BLM 1995).

In northern Arizona, the Prescott National Forest and the Yavapai Ranch have initiated range restoration based on improved grazing management (Whitney 1996). Management objectives included improvement of pronghorn antelope habitat and forage, restoration of critical cover and grassland areas, and improvement of vegetation diversity. Using previously developed best management practices (BMPs) and a coordination structure, the project achieved better vegetative cover and reduced sedimentation. The project used well established management tools like prescribed range fires and controlled grazing to attain these objectives.

Box 3
Possible Options for Restoration on Rangelands

1. Manage land uses and disturbances for a dynamic mosaic of conditions that transitions among different states and retains or restores species richness;
2. Retaining structural diversity, including residual grass cover or regrowth for physical and biological functions, on managed rangeland sites;
3. Retaining and restoring large, intact stretches of rangeland unfragmented by roads;
4. Retaining and restoring corridors and other linkages around settlement areas, along riparian zones, and to forests;
5. Allowing natural fires to burn, using prescribed fire, or applying treatments that simulate fire and other disturbances in order to promote the health of herbaceous and browse plants while maintaining a full spectrum of seral stages and structures;
6. Redesigning road and trail systems, while obliterating and revegetating existing roads and user established vehicle routes; and
7. Recovering viable populations of rare species and reintroducing extirpated species.

Adapted from Noss and Cooperrider (1994);
See also Svejcar and Brown (1992)

Managing recreation use to restore or improve ecosystem function is increasing in importance. With growing populations and recreation demands, more area is affected more frequently by recreation use. Transportation technology has also increased accessibility with the advent of four wheel drive vehicles, specialized motorcycles for trail riding, all terrain vehicles and mountain bikes. Webb and Wilshire (1983) provide options for restoration of vehicle recreation impacts.

While the effects of many vehicle trail uses are different than those on a similar density of roads, leaving large areas open to vehicle use is causing unacceptable levels of impact (USDI BLM 1997; Smith and Pritchard 1992). Millican Valley Off Highway Vehicle Area in Oregon has been open to vehicle use with seasonal restrictions for over 25 years. Almost 500 miles of user created trails have become established in the 65,000 acre area. Drawing from experience and monitoring in a nearby area on the Deschutes National

Forest, BLM is shifting use to a designated trail system of 262 miles and to seasons better designed to reduce impacts to sage grouse, vegetation, soils and other resources (USDI BLM 1997).

4.1.3 Biological Intervention

Efforts oriented around species of concern are common in restoration projects. In some cases, the concern arises because a species appears to be seriously declining or absent, despite apparent availability of suitable habitat. In other cases, the concern arises because an exotic species threatens to displace native species and reduce diversity.

In many regions, invasive species represent one of the greatest threats to ecosystem integrity and one of the greatest challenges for restoration. Federal land managers in many parts of the country can attest to the vigor, reproductive capacity, and tenacity of invasive plants, animals, fungi, and other organisms that were ignored one year and became glaring problems the next. Cheat grass, thistles, Gypsy moth, melaleuca, knapweed, common privet, leafy spurge, hoary cress, Japanese honeysuckle, kudzu, dogwood anthracnose ..., the list is long and growing longer every year (U.S. Congress, Office of Technology Assessment 1993).

In the West, the proliferation of exotic weeds represents one of the greatest changes on arid and semi-arid lands since pre-Columbian times (Allen and Jackson, 1992). Even relict areas are not exempt from invasion by exotic annual plant species (Svejcar and Tausch 1991). Asher et al. (1995) characterized the problem as follows. Exotic plants increased on BLM lands from 2.5 million acres in 1985 to over 8 million acres in 1994. Including exotic populations on Forest Service, National Park Service, and Fish and Wildlife Service lands nearly doubles that infested area. Infestation on these lands is increasing by about 4,600 acres per day.

Exotics as a percentage of total cover have been recognized as an indicator of desertification as aggressive undesirable forbs and shrubs replace natives, spread, or eventually become dominant (Mouat et al. 1993, Dregne 1977). But the impacts are not limited to displacement of native species. Runoff and sediment yield were 56 percent and 192 percent higher for spotted knapweed than for bunchgrass vegetation types (Lacey, 1989). Negative impacts summarized by Huenneke (1995) include influences on native species, soils, nutrient cycling, hydrology, and disturbance regimes (Asher 1996). According to the OTA report (1993: 5):

> "(T)he number and impact of harmful (non-indigenous species, or NIS) are chronically underestimated, especially for species that do not damage agriculture, industry, or human health... From 1906 to 1991, just 79 NIS caused documented losses of $97 billion in harmful effects."

Regional sources of information and assistance in addressing the proliferation of exotic species are generally available. Local county weed supervisors, extension service agents, university weed scientists, and federal/state agency experts can provide information on weed occurrence and effective treatments (Asher 1996). Other groups like The Nature Conservancy and the Illinois Nature Preserves Commission have compiled abstracts on invasive species. The Natural Areas Journal, Restoration and Management Notes, Ecological Restoration, and other periodicals are excellent sources as well. In the West, the "Guidelines for coordinated management of noxious weeds in the Greater Yellowstone Area" and the Lolo National Forest's plan amendment on noxious weed management are good source documents. The Yellowstone document includes detailed guidelines for developing cooperative weed management areas, which can be effective for facilitating cross-boundary action by federal and state land managers and landowners.

The most effective strategies to control exotic plants are generally those designed to prevent establishment and control spread. Cost-effective control techniques are not yet developed for some species once they are well established. An excellent summary of weed control techniques was provided by Harrod et al. (1996). Limiting human activity and surface disturbance reduces opportunities for exotic plants to become established (Asher and Harmon 1995). Potential measures also include using weed-free animal feed, washing vehicles after being in a weed infested area, avoiding seed movement by animals and people, and using weed-free seed (Asher et al. 1995).

Quick detection and control greatly enhances success in treating spot infestations (Asher et al. 1995). Once exotic plants are present, strategies vary depending on species, density, numbers, location, and time of year. Targeted chemical treatment that carefully avoids unintended effects, whether aerial or plant-by-plant, is often the only effective treatment. Mechanical means, most commonly mowing, plowing or discing, can also effectively reduce flowering and seed set (Harrod et al. 1996). Manual removal techniques are most effective when the infestations are small. If native vegetation is not present in adequate densities after treatment of exotics, additional measures may be required to promote native plant establishment and limit re-establishment of exotic species (Asher 1996). In all cases, the timing of control efforts is important to success (see also Case Study 3).

Case Study 3. Restoration and Maintenance of Native Species and Diversity By Control of Noxious Weeds in the West

This case study is a compilation of experiences from public lands around the Western United States. The examples cited occur in Idaho, Montana, Oregon, Utah, Washington and Wyoming.

Geographic Area/Location

On much of the land in the arid West, infestations of non-native plants are an increasing problem, displacing native species and thereby reducing biodiversity. A sample of locations include: Salmon River Canyon, Idaho; Rock Drainage, Montana; Willowa County, Oregon; Millard County, Utah; private land in Yakima County, Washington; Carbon County Weed Management Area, Wyoming

Participants

The participants listed in this case study provide a sample of the people who are working on the problem. They include: private landowners, Idaho County Weed Board, Nez Perce National Forest; Valley County, Montana; Willowa County, Oregon, Oregon Department of Fish and Wildlife; Millard County, Utah's "Scotch Thistle Day" (county, state, private, BLM, USFS, BIA); Yakima County, Washington, Washington State University; Wyoming Department of Transportation, Carbon County, Wyoming.

Restoration Goals

Eradication and control of noxious weed infestations. Many of the successes feature prevention, early detection and prompt action. Target species include yellow starthistle, dalmatian toadflax, spotted knapweed, leafy spurge, scotch thistle, featherhead knapweed, and musk thistle.

Background/Results:

Idaho: The Forest Service's Slate Creek District is developing a Weed Management Program for the Salmon River Canyon. Over 130 spotted knapweed and ragwort sites were inventoried in the Snake River Canyon in 1993. Several sites were pulled/bagged and one yellow starthistle site is believed to have been eradicated.

Montana: Ranchers contribute about four cents per animal unit month to a county weed control fund creating a steady, reliable and continuous fund for combating weed infestations.

Oregon: Weed prevention efforts include a 1991 Willowa County ordinance that makes it unlawful to transport hay, straw or grass (chopped, baled, etc.) that has not been certified as weed free. Volunteers operate hay exchange stations during hunting season and Oregon Department of Fish and Wildlife informs hunters through their hunting proclamation. Since the ordinance, the number of new tansy ragwort sites detected each year has declined by 85 percent.

Utah: Multiple agencies and levels of government have joined to sponsor "Scotch Thistle Day" mobilizing between 200 and 300 junior high and high school students within a 175 miles radius to work on an infested site and learn more about plant ecology. Beyond the benefits of the weed control itself, the education has caused families to adopt the control effort. Goatstrue was imported to the state in 1891 as an attractive forage plant. It was not utilized but by the 1970s over 40,000 acres was infested. Utah decided to embark on an eradication program in 1980. The plant is relatively easy to control and the project was expected to be successfully completed in 1996 at a cumulative cost of $2 million.

Washington: In 1983, a landowner in Yakima County brought in a couple of plants to the County for identification. The plants were feathered knapweed, the only known infestation in North America. The 20×30 foot patch of rhizomatous plants was eradicated using a tordon spray.

Wyoming: In 1992, Wyoming Department of Transportation explored alternatives to repeated investment in weed control along a highway where adjacent lands were also infested. State and county officials, agency employees (federal, state, county) and landowners joined to create a weed management area and developed a plan with shared goals and priorities. The group works with university expertise and is applying biological controls.

Outcomes

The significance of introduced exotic species is being recognized and people are making efforts to address the problem. The weed situation in the Snake River Canyon is better understood and actions to contain and control it have been initiated. Ranchers in Montana have created a stable funding source to address weed infestation problems. Preventing weed infestations is the focus of a local ordinance and volunteer efforts in Oregon. A bridge between eradication efforts and education has been built in Utah. A long term project was sustained in Utah. A weed species unknown in North America was prevented from gaining a foothold in Washington. Biological controls are being tested in Wyoming.

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Although not in common use, biological measures to control exotic plants are receiving increasing attention. Biological controls introduce natural enemies of the exotic plant such as fungal pathogens, herbivores, or parasites. The appeal is cost-effectiveness, in some cases, while the risk is that the control agent will attack native species or produce other unintended results. Apparent successes with insects to control weeds such as spotted and diffuse knapweed, St. Johnswort and purple loosestrife have occurred in relatively undisturbed rangelands and aquatic systems (Harrod et al. 1996). Other biological measures being tested include species specific plant-to-plant competition (e.g., squirreltail/medusahead on clay and clay loam sites), competition stimulated by fertilization, and livestock grazing designed and timed to damage the exotic plant (USDI NBS 1994; Hilken and Miller 1994). The Western Society of Weed Science provides a reference on biological control of weeds in the Western United States (Rees et al. 1996).

Barriers to dealing with weed problems include lack of knowledge of the underlying causes for susceptibility to invaders, lack of suitable biological, physical, or chemical control agents, and ignorance or underestimation of the problems. Use of fire or grazing strategies keyed to plant phenology are promising possibilities. To suppress exotic plant species, grazing treatments should be highly controlled and selective, generally high-intensity, short-duration treatments designed to defoliate and/or prevent seed production in the targeted species (Valentine and Stevens 1994).

Prescribed fire apparently reduces seed production in some exotic plant species and can favor competing grasses (Hilken and Miller 1994, Harrod et al. 1996). For some species, fires can be timed to destroy the viability of seeds. Backing fires downhill and against the wind is most effective with medusahead because it more effectively consumes or damages seeds (Hilken and Miller 1994). Experience in the Murderers Creek watershed in Oregon suggests results can be uncertain, even with careful planning. Winds can shift, converting a backing fire to a head fire. Post-fire precipitation affects success but is difficult to predict. The effectiveness of seeding also affects outcomes where seeding is combined with burning. Yet even with the difficulties, reductions in medusahead are occurring in some areas (USDI BLM Central Oregon Resource Area 1996).

Species of concern also include desirable species, but for different reasons. It is common to design restoration in response to the apparent decline of a desired species. Species decline problems are regularly encountered, but examples of apparently successful reversal of the trend toward local extinction are also evident. Breeding for resistance to disease has enabled managers to be more successful at reintroducing certain western conifers to ecosystems where they have been decimated by exotic and/or native pests (Howe and Smith 1994, Mahalovich 1996).

Animal species once nearly eliminated from many parts of their historical ranges and now increasing in large portions of those ranges include the wild turkey, black bear, beaver, American alligator, bald eagle, white-tailed deer, wood ducks, several species of trout, herons, egrets and shorebirds (USDI Fish and Wildlife Service 1987). Habitat restoration on federal lands has played, and will continue to play, a key role in the many states and regions where these success stories unfolded. The desired outcome is usually simple: recovery in a specified area for a self-sustaining population of a species that was nearly eliminated within the past two centuries. In some cases, the desired outcome includes recovery to the point that regulated hunting or fishing is possible.

Success generally comes easier with species that are habitat generalists rather than specialists. State wildlife agencies, in cooperation with federal agencies, have spearheaded efforts involving habitat generalists, efforts which often required the commitment of several agencies operating as partners across state boundaries. Sometimes, federal land managers have been partners, not initiators, a role which is likely to continue to be appropriate. Two obstacles to success are (1) threats or perceived threats to livestock, private land values, and/or management options posed by the reintroduction/recovery effort and (2) insufficient understanding of predator–prey and/or habitat relationships. Lack of local genetic material may also be a problem (see Holthausen, this volume).

As suggested by the listing of recovering species above, much of the habitat restoration focus in previous decades has been on species of social interest, such as game species. For example, few elk were present in eastern Oregon and Washington from 1800 until about 1930 but now they are much more common (Johnson 1994). But as the number of game species has grown, predators have been displaced. This change also has implications for the plant species these large herbivores browse (*ibid;* Blue Mountain Natural Resources Institute 1996).

Species recovery activities in some instances have turned out to be highly compatible with active human use and management, and even produced some surprising side benefits. Peregrine falcons, for example, are becoming more common in urban settings. The Sierra Club issued an award to national forests in Florida for their efforts on behalf of the Florida scrub jay, efforts that included clearcutting and burning. In western Arkansas, the Ouachita National Forest has designated a new management area in which ecosystem restoration and eventual recovery of a red-cockaded woodpecker population are key objectives that can be accomplished without reducing timber sale volume for at least 20 years (USDA Forest Service, Southern Region 1995).

Other species, including perhaps most of the officially listed threatened or endangered species in the United States, have not fared as well. The Nature Conservancy's Annual Report Card for U.S. Plant and Animal Species (The Nature Conservancy 1996) listed 6,246 plants and animals rated either critically imperiled, imperiled, or vulnerable. Of the 3,170 species considered critically imperiled or imperiled, 80 percent are vascular plants. Falk et al. (1996) cover the strategic and legal context for rare plant restoration and provide case studies from across the United States.

Case studies of prominent endangered species recovery programs are profiled by Clark et al. (1994). As of September 30, 1988, six of the ten species delisted were due to extinction and four were due to recovery (Meese 1989). However, these counts may not be an accurate predictor of current and future trends; successes in addressing species rarity and decline are occurring (Clark et al. 1994). More holistic considerations such as species rarity, endemism and richness have not previously received much attention, but they are an increasing focus in the management of federal lands (Quigley and Arbelbide 1997).

Species recovery may be a long-term, costly venture. It can become socially and politically controversial as well, as in the cases of wolf reintroduction, grizzly bear recovery, and red-cockaded woodpecker recovery. Other barriers to restoration include: (1) recovery of habitat specialists is often a slow process, during which political and financial commitments may weaken, and (2) scientific information about the species of concern may be inadequate.

Some of the most promising possibilities for long-term species recovery are the emerging ecosystem-based approaches, e.g., those developed in response to threats to the red-cockaded woodpecker (USDA Forest Service, Southern Region 1995) and anadromous fish (Columbia Basin Salmon Restoration efforts). The likely success of these efforts will be their ability to weave together the social, economic, and ecological elements of a sustainable recovery. The expected solution is likely to include a variety of management techniques across large landscapes, although the emphasis is on structural treatments and managing land uses differently (Interior Columbia Basin Ecosystem Management Project 1997).

4.2 Summary for Terrestrial Restoration

The shift to ecosystem management has turned attention to management treatments such as prescribed fire to affect vegetation positively, the importance of managing land uses with ecosystem function in mind, and the potential to carefully intervene to restore or protect biological attributes. These restoration techniques can promote ecosystem health by improving process function and changing the structure and composition of plant and animal communities. Even though social and economic factors continue to affect land management decisions, efforts are underway to integrate them with ecological function to create a sustainable whole. Though some restoration problems, such as controlling aggressive exotic species, are growing in severity, experimentation to develop new and more reliable restoration techniques is also underway.

Habitat changes, particularly in old-growth forests, are receiving considerable emphasis across the nation. Habitat restoration is being addressed at broader scales to consider communities across watersheds, landscapes, and regions. But this change in emphasis is fairly recent. As a result, it is difficult to assess the long-term, large-scale effect of many habitat restoration efforts. Clearly some projects are producing desired results.

5 APPROACHES TO TREATING RIPARIAN FUNCTION

Scenario: Stream systems are impacted by loss of vegetation, bank instability, sedimentation, changes to the channel or elevated water temperatures.

Impaired or reduced riparian function occurs where historical or present land uses have disrupted physical and biological processes. Nonpoint source pollution is commonly tied to agriculture, forest practices, construction, mining, recreation, urban runoff, and land disposal within the watershed (Johnson 1992). The general categories of problems to be addressed through restoration based on Platts (1989) and Johnson (1992) are:

- Alterations of streamside vegetation and soil conditions
- Changing channel morphology (water velocity, water table)
- Altered water temperatures, nutrient loads, sediment loads, bacterial counts
- Degradation/erosion of stream banks

Lack of instream habitat structure is also important. Riparian restoration to improve water quality, fish and wildlife habitat, and the general health and aesthetics of the stream is becoming widespread and common in every region of the country, although many efforts are in their early stages (Natural Resources Law Center 1996). The National Research Council (1992) has also compiled a very comprehensive text covering restoration of aquatic systems.

The Government Accounting Office, after reviewing 22 stream restoration efforts in the West concluded there were "no major technical impediments" to riparian restoration (USGAO 1988). Systems for classifying riparian community types and channel types are well developed with solid insights into stream function, species composition, fishery potential, and forage production (Gebhardt 1990, Hansen et al. 1995). Practical and useful techniques to assess the physical and biological attributes of the stream are also well documented (Batson 1987, Myers 1989, Hunter 1991, Leonard et al. 1992, Cagney 1993, Pritchard et al. 1993, Pritchard et al. 1996, Hindley 1996). Most current restoration projects are developed in a watershed context.

Successful restoration efforts consider the complex relationships of riparian function and the integral role of vegetation (Elmore and Kaufman 1994). Hunter (1991) suggested that success is dependent on understanding the physical, chemical, and biological attributes of the stream and on the ability to analyze these diverse sets of data. The indicators that recovery is occurring have been described by Elmore and Beschta as follows:

> "As vegetation becomes established along a stream, channels typically begin to 'aggrade', that is the streambed will rise as sediments accumulate... As more sediments are deposited and bank building continues, particularly along low gradient stretches, the water table rises... More water is stored during wet seasons, and its gradual release may allow a stream to flow during the driest of summers... The gradual release of water from increased underground storage can more than offset the water used by streamside vegetation." (Elmore and Beschta 1990, pp. 9–10)

Classifications and rapid assessment techniques for proper functioning condition provide useful tools to evaluate stream channels and systems for setting goals and objectives. Rosgen (1994, 1996) developed a commonly used classification system for understanding stream channel morphology. Assessing proper functioning condition can be used to set restoration priorities by identifying areas which are functioning properly, functioning at risk, or not functioning properly (Pritchard et al. 1993).

5.1 Management Options for Riparian Restoration

Options for restorating riparian systems are grouped into the three different approaches discussed above: structural treatments, management of land uses, and biological intervention. In many cases they have been combined and each approach includes techniques which are directed at accelerating positive ecological change in the riparian zone. Compilations of case studies are available to review work done in similar settings (Appendix B).

5.1.1 Structural Treatments

Early approaches to restoration often involved engineering the physical attributes of a stream using structures. In 1933–1935, the U.S. Bureau of Sport Fisheries put in 31,084 structures in 406 mountain streams. Many are still in place; some are not. By 1952, the Forest Service Fish Stream Habitat Improvement Handbook recognized that structure work was not a "cure-all," could be overdone, and could cause damage (Hunter 1991).

Experimentation with structural approaches to bank stabilization and instream modification continues today. As expected, experience has taught a few lessons. The most important is that structures are not a substitute for managing land uses (Elmore and Beschta 1989). Structures can be both expensive and ineffective if land uses adversely affecting the stream are not corrected (Elmore and Beschta 1987, Hunter 1991, Beschta et al. 1991) Determining where, and if, to place structures may be best deferred through several years of stream recovery after changes in land use or biological intervention (Elmore and Beschta 1987).

Structures are generally used for bank stabilization, channel aggradation, and instream habitat improvement. Rock rip rap has been commonly used to stabilize banks for many years. It has proven effective when rock is properly sized. However, it generally changes the character of the streambank, is expensive, and may cause problems downstream.

One of the most promising bank stabilization techniques is the use of trees anchored along eroded streambanks to catch sediment and reduce water velocity. Cut juniper trees anchored along eroded streambanks proved beneficial in stabilizing 96 percent of the erosion on eight streams evaluated in Eastern Oregon over a 14-year period, mainly on straight or slightly curved banks. Water velocities were reduced by 65 percent where juniper revetment was evaluated. Failure occurred on outside curves or where poorly anchored (Sheeter and Claire 1988). Tree revetment is a relatively low cost approach ranging from $4 to $40 per meter depending on site specific factors (Sheeter and Claire 1988). Brush deflectors were found to be similarly effective on stream systems in California (Meyer 1988). Even when the revetment fails because the trees were not cabled because of concerns about bank loss, the riparian response may be positive (Munhall 1996).

Success with instream dams to raise stream levels has been mixed. Some have failed because the gradient was too steep, others because the materials used were inadequate, and still others because they were inappropriate to the stream system. Structure failure also can occur where the stream gathers too much velocity upstream of the treated stretch. "Hardening" of some stream channel segments may be inappropriate (Beschta et al. 1991). If a check dam approach is used, it is important 1) to tie the project to channel type and gradient (low) and 2) to develop rock sources a year in advance (Munhall 1996).

Responses to instream structures that enhance fish habitat are well documented. Woody debris is correlated to the quality of fish habitat and lack of woody debris has been suggested as a factor in the decline of wild stocks of coho salmon in the Northwest (House and Boehne 1986). Placement of instream woody debris and other instream fish structures is common and has a history of success in increasing fish numbers in many stream settings (Reeves et al. 1991, Crispin et al. 1993, Solazi 1995). However, the benefits are not always clear and structures may actually cause problems. Cost-effective restoration efforts such as debris placement need not be a separate project and can occur as part of logging operations (Skaugset et al. 1994).

Instream structure projects often involve transporting and placing logs or other flow deflectors in stream channels dominated by riffles and degraded to the substrate. Causes vary from logging and grazing to floods and stream cleaning. Treatment can be a combination of full spanning structures to create pools, partial spanning structures to maintain pool depth, and bank deflectors. Some projects include construction of off-channel areas and cabling of log and rock placements. Structures are effective in catching additional large woody debris (Crispin et al. 1993).

Instream structures are commonly associated with restoration projects, and many have improved fish population numbers. Although instream structures are common and considerable literature is available on "bioengineering" streams to improve fish habitat, structures can be installed that widen the stream, limit gravel bar formation, or create erosion (Beschta et al. 1991). In some cases, woody material has been introduced into meadow systems where it probably was not present before. The best timing for introduction of instream structures is debatable. Some argue for a coordinated approach so all project features can work in concert to reduce the impacts of major runoff events and improve habitat (Terrene Institute 1994). These may be site-specific decisions that need to be based on stream channel characteristics and conditions.

The focus on the relationship between roads and riparian resources has shifted over the last 30 years. Road construction and maintenance used to focus mainly on keeping the road dry, safe, easy to travel, and conveniently located (Terrene Institute 1994). More recently, road construction and maintenance efforts have begun to address environmental problems related to concentrated flow, accelerated runoff, water table effects, sedimentation, and barriers to stream flow (Terrene Institute 1994).

Road design and location are important. A wide gently climbing road in a steep watershed disturbs more soil material than a steeper, narrower one climbing the same slope (Brown 1980). Road drainage water was responsible for about one-quarter of the road related mass soil movements on the H.J. Andrews Experimental Forest, and about 45 percent of the volume of material moved in the winter of 1964–65 (Brown 1980). Poor road design can yield mass soil movement and surface erosion while techniques such as compaction of fill materials, minimizing side cast material and use of excavators for construction can benefit riparian resources (Brown 1980).

Strategies to address road-related problems include closure, realignment, surface changes and crossing changes. The redesign of culverted crossings has shown clear and consistent benefits. But a wide variety techniques can significantly improve bank stability, reduce sedimentation, improve channel stability, and reduce headcutting (see Box 4).

Periodic fluctuations in water quantity and flow are essential to any riparian system. But some systems have been altered by impoundment (dams) or diversion, making water availability an issue. In one of the most interesting riparian restoration cases underway, restoring flows to a previously de-watered stretch of the Owens River Gorge in California represents an attempt to re-establish a functional riparian system. Hill and Platts (1995, p. 16) indicate "The key to ecosystem recovery and continued health in the Gorge is a multiple flow regime that allows nature to build and maintain riparian habitat." The important point here is the system dependence not just on the presence, absence, or amount of water, but also on a flow regime that increased flows to coincide with the reproductive cycle for cottonwoods. Also promising are the releases from Glen Canyon Dam in an effort to restore beaches and fish habitat in the Grand Canyon.

5.1.2 Managing Land Uses

In identifying what problems to address, the starting point is to understand the causes of decline (Elmore and Kaufman 1994). That focus may often lead away from engineered solutions to management of land uses. DeBano and Hansen (1989) recommend using a systems approach to evaluate existing conditions, cause–effect relationships, landscape–vegetative potential, land use management, and maintenance. Where the cause is tied to a current land use, the incompatible use may simply need to be "conducted

Box 4
Suggested Actions for Road Management and Riparian Restoration

1. Disperse drainage rather than concentrating it.
2. Avoid discharge of large amounts of runoff into non-drainage areas.
3. Avoid changing natural drainage patterns when placing culverts or waterbars.
4. Design road surfacing for erosion control during the wettest period of use.
5. Control use on roads deigned only for dry season use.
6. Outslope drainage when possible.
7. Provide frequent drainage relief, avoiding areas prone to gullying, slumping or landslides.
8. Place energy dissipators at drainage outlets and crossings.
9. Provide for vegetative or mechanical stabilization to mitigate for erosion. Consider larger material to support the roadbed or surfacing with gravel, etc.
10. Keep approaches to streams as close to right angles as possible.
11. Minimize streamside disturbance.
12. Provide special design consideration to crossings including stream diversion, disturbance limits, equipment limitations, erosion control and timing.
13. Consider the use of retaining walls where practical.
14. Design culverts for peak flows.
15. Design culverted roads to avoid the potential for flows down the road even if a culvert is plugged.
16. Field check all riparian-related road designs.
17. Consider the benefits of providing for fish passage or isolating a fish population.
18. Close roads near streams or relocate roads away from streams.
19. Reduce road densities within the watershed.

(Modified from Furniss et al. 1991)

differently, relocated or eliminated to allow the riparian vegetation and stream channel to recover" (Hunter 1991, p. 123). On its surface, the process of managing uses for riparian restoration is a simple cycle of steps: highlight problem areas, decide what to work on (objectives), evaluate alternatives, put action into practice, and watch for results (Adams and Fitch 1995).

In identifying a problem's cause, Hunter (1991) and Reeves et al. (1991) suggested trying to find the "bottleneck" by following an orderly review of seasonal land uses, streambank conditions and instream conditions. Often, the clues to a strategy which will be successful are in comparable case studies that address similar land uses in similar settings (see Box 5).

A possible source of confusion is that historical factors affecting current riparian conditions may be difficult to separate from current land uses. For example, fur trappers in the late 19th century eliminated beavers from some streams in the Pacific Northwest. The loss of beaver ponds affected the extent of floodplains, the erosive power of floods, sedimentation, and organic debris (Elmore and Beschta 1987). Another example would be the 1964 flood on the John Day River in Oregon which lowered the water table, caused hay meadows to erode, created the need for irrigation, and led to straightening and "control" measures. The results were increased velocities, cutting of the bed and banks, and loss of fish habitat quality (Hunter 1991). Even though grazing is the current land use, historical practices and modifications are often key restoration considerations (Robbins and Wolf 1994, Todd and Elmore 1997).

Sorting barriers to riparian improvement sometimes takes careful analysis and participation by individuals with different perspectives. The primary focus for stream restoration is restoring streamside vegetation (Elmore and Beschta 1987). It would seem an easy goal to support. Yet even when diverse interests commit to work together to solve riparian problems, events sometimes occur that break any trust which develops (Natural Resources Law Center 1996). See Case Study 4.

The removal of vegetation in the riparian zone or the watershed is generally a primary cause of problems with bank stability, sedimentation, water quality, and changes in instream characteristics. In many cases, livestock grazing and timber harvest practices have contributed to poor riparian conditions on public lands (DeBano and Hansen 1989).

Where grazing has been tied to the problems observed, changes in grazing are an essential part of the solution. Biologically, the simplest change employed has been to exclude cattle from all or a portion of the riparian zone; this action has consistently resulted in recovery (Elmore and Kaufman 1994). Commonly noted exceptions are where trespass has occurred or

Box 5
Guidelines for Identifying Causes that Limit Stream Recovery

1. Land use is important because it generally is an aspect affecting limiting factors and project planning. Problems related to similar uses are often similar.
2. Landscape setting is valuable because solutions can often be generalized to other forested, agricultural and suburban landscapes.
3. Land use and setting often correlate well to physical stream properties such as gradient and channel type.

(Modified from Hunter 1991)

Case Study 4. Willow Creek/Whitehorse Creek: Trout Creek Mountains, Oregon

This case study involves evaluation of riparian functions, identification of restoration objectives and management of livestock grazing in the Great Basin of southeast Oregon near the Nevada border. Restoration is being addressed at the larger watershed and landscape scales. But perhaps most importantly, this case involves creating a collaborative solution in the midst of contentious and controversial issues surrounding an endangered fish species and three Wilderness Study Areas.

Geographic Area/Location

The Whitehorse Butte grazing allotment includes 127,000 acres of rugged topography, ranges in elevation from 4,000 to 8,000 feet, and receives annual precipitation of 8 to 12 inches. Willow Creek and Whitehorse Creek (and their many tributaries) are the major streams within the allotment. With 64 miles of stream, many canyons are ribboned with riparian zones comprised of willows, alders, sedges, rushes and grasses. The most extensive riparian areas are along Willow, Whitehorse, Little Whitehorse, Doolittle and Fifteenmile Creeks where Lahonton cutthroat trout were documented in 1991.

Participants

Vale District of the Bureau of Land Management, Trout Creek Mountain Working Group, Fish and Wildlife Service, Oregon Department of Fish and Wildlife, landowners and ranchers.

Restoration Goals

The goal for 64 miles of creek in the Whitehorse Butte Allotment was to improve those with medium or high potential that were in poor or fair condition to good or excellent condition by 2010. Additional objectives included: (1) reversing downward ecological trends in pastures where they were occurring, (2) maintaining or improving ecological trends elsewhere, (3) stabilizing all meadow soils to alleviate head cutting and loss of meadow by 1995, and (4) managing for aspen regeneration and survival to assure perpetuation of the stands by the year 2010.

Background

Livestock grazing had occurred on the Trout Creek Mountains during the summer with little change between settlement in the late 1800s and 1970. In 1970, a 2-day horseback tour of the allotment revealed deep gullies with active cutting, little shade from riparian vegetation, and warm water temperatures. BLM initiated projects planting willows and installing 49 trash collector check dams. In 1973, BLM completed a Habitat Management Plan for the Whitehorse and Willow Creek watersheds. Eight miles of stream were then fenced to create a riparian pasture and small watering ponds were built. Substitute livestock forage was developed in three crested wheatgrass seedings. In 1986, several (additional) exclosures were constructed to exclude livestock from three miles of Willow Creek.

In 1987, tours of the Whitehorse Allotment began to occur regularly. In 1988, the Trout Creek Mountain Working Group was formed to include a cross-section of representatives of environmental, ranching and agency interests. The expressed purpose of the working group was to see that management was changed immediately to make a positive difference on the land. The working group sought to create solutions by building trust, respect, credibility and communications among people with very different perspectives on the problems identified.

In July of 1990, BLM issued a grazing decision to balance livestock grazing and other resource values, building on a 1988 "three year rest agreement" reached with Whitehorse Ranch. The ranch had agreed to rest approximately 50,000 acres of the allotment to allow for riparian and watershed improvement. BLM agreed to develop an allotment management plan to maintain positive ecological trends by meeting the physiological needs of plants. The area was also closed to fishing in 1990. BLM and Whitehorse Ranch agreed upon the grazing plan in 1991, reducing livestock numbers as well as changing the timing, duration and frequency of use. To implement the proposed grazing system, three fences (14.75 miles), one creek exclosure, one reservoir, one spring development, two fence removals (6 miles) and four pipelines were proposed to change the timing and distribution of livestock use over the 127,000 acre area. Lahonton cutthroat trout were listed as an endangered species in 1991.

The project area, although very remote, includes several public values of note. Bighorn sheep have been successfully reintroduced into the area. Recreationists visit Willow Creek Hot Springs and use the area for hunting. Three Wilderness Study Areas and important archeological values are also present.

Results/Outcomes

The trash collector check dams met with limited success, with 60 percent washing out within three years. Upward trends are apparent on all streams within the allotment. Substantial increases in the size and volume of woody species were noted on all streams. Streambank cover has increased on all streams. Estimates of fish populations in 1994 by the Oregon Department of Fish and Wildlife were 40,000 fish, an increase attributable to riparian improvement and cessation of drought. Recreation use at Willow Creek Hot Springs has doubled, although deer numbers and hunting use have dropped. Monitoring indicates the overall vegetative trend has been upward since 1989.

Reference:

USDI Bureau of Land Management, Whitehorse Butte Allotment Management Plan 1991; Whitehorse Butte Allotment Evaluation 1996 and Doc and Connie Hatfield 1994. History of the Trout Creek Mountain Working Group, 1988–1993 and Michael R. Holbert 1991. Whitehorse Butte Allotment — Controversy to Compromise. *Rangelands* 13(3).

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fences are not maintained. Even one or two head of cattle in the riparian zone at the wrong time can hurt progress on restoration if they are left along the creek too long (A. Munhall, personal communication 1996).

But changes in the management of livestock grazing can also be an important part of the solution, avoiding the large expenditures often required to exclude livestock from riparian areas (Elmore and Beschta 1987, Kinch 1989). The dominant considerations in designing a solution are to meet the physiological needs of the plants and to ensure adequate vegetation growth to stabilize banks during periods of high runoff (USGAO 1988, Elmore and Beschta 1987). This often involves changing the timing, duration, or frequency of grazing use. These strategies and their relationship to riparian plants and bank stability have been evaluated and rated by Elmore and Kaufman (1994). Information on grazing system compatibility with various stream systems has also been compiled by Platts (1990). Johnson (1992) covered the relationship between grazing practices, infiltration, and sediment production. More specific information is also available on the compatibility of grazing systems with willow regeneration (Kovalchik and Elmore 1991).

Evidence indicates that (1) total livestock exclusion is not necessary on many streams, (2) livestock grazing and healthy riparian systems can coexist during recovery, and (3) grazing management changes may be as effective as exclusion on some sites (USGAO 1988, Elmore and Beschta 1987). Improvement in the management of livestock grazing can produce dramatic results. The riparian zones on many creeks in BLM's Prineville District in Oregon have nearly doubled in width and acreage in response to changes in the season, duration, and frequency of grazing over a 15-year period, while the creeks became deeper, clearer, and colder (Rasmussmen 1995). See Case Study 5.

One of the most important technical considerations in managing grazing in riparian areas is the size of the pasture. If it is a riparian pasture with considerable acreage in uplands, the whole pasture is then managed to meet riparian objectives. This could be an important economic and biological constraint depending on the desired season of use for the uplands. A smaller riparian pasture allows more targeted management for both the riparian area and the uplands, but the riparian pasture needs to be large enough to provide for effective livestock management. Disadvantages of riparian corridor fencing include cost of construction, maintenance problems and costs, and loss of forage (Beschta et al. 1991, Munhall 1996). Mitigating for visual impacts and potential for damage to big game animals are also important design considerations (Beschta et al. 1991).

Summer grazing has been continued in several cases, although the tendency is to incur significantly heavier utilization by livestock in the riparian zone during the hotter months. Moving livestock based on utilization levels may necessitate changing forage allocations, additional management measures (e.g., herding), and more intensive monitoring to ensure moves are timely (Munhall 1996). Timing grazing moves to meet the physiological needs of the plants and to allow vegetation regrowth to meet the physical needs of stream function may require use of techniques such as herding, additional fencing, and more frequent moves. Reliance on reducing numbers of livestock or utilization targets may lead to improvements in the upland vegetation, but the riparian zone is not likely to improve (Platts 1990). In cases where changes in the amount of livestock grazing (numbers or utilization) did not produce the desired riparian improvement, a change in timing may have been more successful.

In sampling 22 riparian areas in 10 Western States, the GAO (USGAO 1988) noted that the overriding factor in achieving success was improving the management of livestock to meet the life-cycle needs of native vegetation by herding and/or fencing often in combination with a shorter grazing period, a specific season of use, or limitation to a portion of the area. Moore and Flaherty (1996) also noted that grazing systems need to adapt the frequency and seasonality of use in response to site specific characteristics, year-to-year trends, and seasonal changes.

Logging practices also affect riparian condition, but experience with varied restoration strategies is not as well-developed as with grazing. Logging factors generally include the amount of harvest allowed or the prescribed buffers established to exclude it. Available case studies suggest more complex species- or site-specific strategies are much less common. The logging-related problems most consistently identified have been modified plant composition, loss of woody debris (long term), sedimentation, streambank damage, and erosion.

As with grazing, the streamside zone is a distinct management unit in a forest watershed that deserves special attention based on its sensitivity, variability, and complexity (Brown 1980). Yet little work has been done regarding the effects of forest practices on riparian function, other than the recruitment of large woody debris (Reiter and Beschta 1995). The most widespread forestry approach is to exclude or limit activities in the riparian zone (Moore and Flaherty 1996). This same approach applies to avoidance of disturbances that may damage upslope stability (Swanston 1974). Avoiding use-related impacts allows stream structure and processes to function, promotes higher infiltration rates, and minimizes surface runoff (Brown 1980).

Case Study 5
Bear Creek, Crook County, Oregon

This case study involves evaluation of riparian functions, identification of restoration objectives and management of livestock grazing in the Columbia Plateau of Central Oregon. The restoration effort integrated structural treatments such as juniper revetments, but emphasized changes in livestock grazing. Data gathered in the late 1970s and early 1980s allows a longer term assessment of these changes than is available in many locations. Significant improvement in riparian conditions occurred with exclusion of livestock grazing and with grazing management strategies appropriate to the riparian area.

Geographic Area/Location
Bear Creek is a 42 mile tributary to the Crooked River that flows into Prineville Reservoir in Central Oregon. The 16 miles of creek managed by the Bureau of Land Management are in a 12 inch precipitation zone at elevations of 3,400 to 4,000 feet. Soils are sandy loams. Grazing management practices are coordinated with adjacent areas managed by the Ochoco National Forest and by private landowners/ ranchers. The stream segments in Bear Creek which were surveyed total approximately 7.5 miles. Historically, the primary riparian communities were willow/birch and sedge/ rush/grass. The creek includes a population of redband trout and beavers are present. Flood events are most commonly due to storms which intensify late winter runoff or summer thunderstorms.

Participants
Prineville District of the Bureau of Land Management, Ochoco National Forest, landowners and ranchers.

Restoration Goals
The goal for Bear Creek was to restore riparian function while also improving upland vegetation. Problems identified were reduced riparian vegetation, incised channels, and large movements of sediments. Work was to be coordinated with efforts to reduce erosion and sedimentation into Prineville Reservoir. The principal management objective was to protect streambanks against erosion by high flows during spring runoff and high intensity summer thunderstorms.

Background
Livestock grazing has occurred on Bear Creek since the 1800s and was typically summer-season long. By the 1970s, most of the stream was in poor condition. In 1973, BLM completed a watershed plan for Bear Creek. The timing and duration of livestock use was changed to better coincide with the needs of the plant species present so they could contribute to hydrologic function. Surveys of riparian conditions, habitat use, water quality and bank stability were conducted on about 400 miles of streams in the Prineville District in the late 1970s and early 1980s. Bear Creek was one of the areas covered by the surveys.

An exclosure was placed along Bear Creek in 1978. Strategies to schedule livestock grazing (e.g: deferred rotation and winter/spring use) were expanded in 1978. Juniper rip rap was placed against selected eroding riparian banks in 1982. BLM cut upland juniper trees from parts of the watershed and divided the riparian area into three pastures in 1985. Juniper treatments for watershed improvement purposes had been occurring in the watershed since mid-1970s.

Results/Outcomes
Dramatic changes have occurred in riparian condition between 1978 and 1994. In most cases, grazing has continued but is managed to control when and how long the livestock are present to fit the needs of the riparian zone. Based on the 7.5 miles sampled in four segments, the size of the riparian plant community has increased by 76 percent. The area affected by eroding and damaged banks has declined by over 90 percent. Seventeen to 26 percent increases in the grass-sedge-rush community occurred, with corresponding increases in litter and decreases in forbs and bare ground. In some areas beaver activity has greatly increased.

Considering most of the streams resurveyed in 1994, these results are not unusual. Most other streams also appear to be in better condition in 1994 than they were in 1978. It is important to note that aggrading and expanding riparian systems may experience a loss of shrubs and woody species depending on the substrate. Some occurs because riparian shrubs cannot tolerate year-round saturated soils. But even some riparian species require well drained soils which may not be present under some circumstances. Available data supports the contention that improvement of riparian condition can and will occur with a change to an appropriate grazing management plan if grazing was instrumental in causing the deterioration.

Reference
Rasmussen, Christine. 1995. Riparian Community and Bank Response to Management: A Comparison of Old and New Surveys in the Prineville District, Bureau of Land Management; Chaney, Elmore and Platts. 1990. Livestock Grazing on Western Riparian Areas. Environmental Protection Agency.

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Historically, forest practices have dramatically altered stream channels with splash dams, stream cleaning, increased frequency of debris torrents, sedimentation, streamside harvesting, and the reduction of large wood in channels and riparian areas (Reiter and Beschta 1995). But with the wide range in forest practices and ecological sites, it is also clear that even though forest practices can significantly alter hydrologic systems in some instances, in others they may have little or no effect (Reiter and Beschta 1995). There is no substitute for site specific analysis. Harvest dispersal can mitigate impacts (Harr 1981). However, modification of harvest levels alone, although attractive in its simplicity, is often not as relevant to mitigating impacts as how and where harvest occurs (Reiter and Beschta 1995).

A "Best Management Practices" (BMP) approach is commonly applied to timber uses. The effects of BMPs on sediment discharge have been documented. Erosion rates from roads can be reduced by 80 percent, whereas rates from harvest areas can be reduced by 35 percent by employing BMPs (Rice 1992). BMPs generally direct special attention to perennial streams and the recognizable area dominated by the riparian vegetation. The intent is to avoid management practices that cause detrimental changes to water, stream channels, erosion, or fish habitat (Harr 1981).

BMPs can reduce sediment delivery to streams by reducing soil compaction, and thus erosion at peak flows (Brown 1980). Examples of alternative harvest systems which can significantly reduce compaction and soil disturbance include small, low-cost cable logging systems on slopes over 30 percent, intermediate supports to extend lift, low ground pressure vehicles, and designated skid trails (Brown 1980). Techniques such as uphill or parallel felling to minimize soil and vegetation impacts also lower the susceptibility to erosion. Yarding systems that lift logs off the ground or uphill yarding to avoid concentrating runoff can also reduce erosion (Moore and Flaherty 1996). Although sedimentation depends on both erosion processes and forest practices, the effects of sediment loading generally decrease as the distance to the activity from the stream increases (Reiter and Beschta 1995).

The effectiveness of buffer strips has been repeatedly demonstrated as a technique to maintain desired stream temperatures. A 50–80-foot buffer strip on Little Rock Creek in Oregon was nearly as effective at maintaining temperature as an uncut forest stand (Brown 1980). Leaving a buffer when applying fertilizer or avoiding slopes where it may readily flow into sensitive areas also helps protect stream water quality (Moore and Flaherty 1996). But buffer strips can also result in increased blowdown, bank damage, and, potentially, increases in temperature (Brown 1980). Buffers also have limited ability to filter sediments resulting from upslope erosion. For buffer strips to be most effective, they must be designed based on the steepness of slopes with gradual transitions between buffer strips and cut areas (Moore and Flaherty 1996).

The degree of shading in a riparian zone, rather than the width of the buffer, is probably the best predictor of effects on water temperature and long-term fish habitat quality (Gregory et al. 1977, Moore and Flaherty 1996). The direction of stream flow is also significant in evaluating shading, with the north side of a stream providing little shading and shading being naturally limited on north–south flowing streams (Brown 1980).

Although forestry practices can potentially alter long-term solar radiation, water temperature, sediment, nutrients, litter inputs, woody debris and channel structure, canopy removal may also cause some short-term increases in fish production (Gregory et al. 1977, House and Boehne 1986). But the ability of the stream to retain algae and litter inputs is closely tied to large woody debris (Gregory et al. 1977). Sedimentation or decreased substrate stability may also decrease abundance of aquatic insects and thus affect the food supply for fish (Gregory et al. 1977).

Site characteristics around the riparian zone are also important. For example, shallow granitic soils after saturation during high intensity rain storms are more prone to slides because of rapid increases in pore water pressure that lubricate the soils and affect sheer strength (Swanston 1974). When timber harvest occurs, sheer strength changes as root strength declines over the following three to five years, particularly on shallow soils and steep slopes (Swanston 1974, Harr 1981). Areas of higher soil instability are often associated with improper placement or design of logging roads (Swanston 1974; see also the discussion of roads above.). With these factors in mind, riparian and stream function restoration begins with forest practices upslope in the watershed.

Intensive recreation use occurs in many riparian zones because they are preferred environments for fishing, camping, picnicking, hiking, and other uses. Problems arise when the location, timing, and intensity yields multiple trails, heavily used campsites, and vehicle routes in the riparian zone. The effects on vegetation and soils include compaction, root exposure, loss or change of vegetation cover, change in the soil profile, reduction in organic matter, increased bulk density, and decreased soil moisture (Clark and Gibbons 1991). Most recreation impacts occur as new uses are introduced into an area with little or no previous use, while continued or increasing recreation use in areas with heavy uses may have little additional effect (*ibid*).

As a result, the most effective approach to managing recreation impacts is to direct use, harden sites and exclude use on other sites. Recreation use density decreases with distance from access points (Clark and Gibbons 1991), and use levels at some sites can be controlled by relocating or closing roads, trails and parking areas. Improving a primary road or trail, while closing other routes, can successfully redirect recreation use (Caffrey and Rivers 1993; USDI BLM Deschutes Resource Area 1996). The response in areas where use is excluded is roughly similar to vegetation and bank stability improvements described for exclusion of other uses.

Successful restoration in managed recreation sites often relies on the ability to direct use to "hardened" sites while closing more sensitive sites. As with roads and trails, facilities such as launch ramps, docks, restrooms, tables, fire grates, shelters, parking areas and signing have tremendous influence over the distribution of use (Clark and Gibbons 1991; Smith and Pritchard 1992). Properly located, they can attract use away from sensitive areas. This allows an outlet for recreation use pressure and localizes impacts to an area that can be surfaced with gravel or some other agent to enhance stability and retard erosion (Moore and Flaherty 1996; USDI BLM Deschutes Resource Area 1996). Reducing the area of bare soil and associated areas where vegetation is dominated by annual species improves streambank stability and riparian area composition as a whole.

Managers tend to be more aware of recreation impacts than visitors (Clark and Gibbons 1991), suggesting that one solution is to do a better job of making information available about riparian potential and trends. Many interest groups have become involved in riparian restoration projects and direct involvement enhances awareness (Clark and Gibbons 1991). Once recreation users understand the need for restoration effort, they are more likely to comply with closures and restrictions.

5.1.3 Biological Intervention

In many cases, desired riparian species are absent or declining. Some restoration strategies have centered around reversing declining trends of a specific species or re-establishing a species that is absent. Intervention on behalf of a riparian plant species is similar in concept to wildlife species intervention or reintroduction. Just as steps are sometimes taken to promote one wildlife species by controlling a predator or a competing wildlife species, strategies have also been developed and applied to promote restoration of selected riparian species.

Causes of riparian problems are not limited to human uses. Grazing by ungulates (deer and elk) also contributes to altering plant cover, causing soil compaction or disturbing sensitive soils in some areas (Gifford 1981, Edgerton 1985). Exclusion of deer and elk can increase crown cover and the cover of grasses and sedges (Tiedemann and Berndt 1972; USDA Forest Service, Aspen Working Group 1995; Shepherd 1996).

Although grazing by big game and other species is not frequently addressed in riparian restoration, it can be a factor where predators or other factors are insufficient to limit big game populations (Chadde 1989, Crowe 1996). Foraging by deer and elk can retard establishment of some riparian species (Beschta et al. 1991, Chadde 1989, Emmington and Maas 1994), with subsequent effects on bank stability and riparian function. In some areas, the most common cause of riparian plant mortality or retardation of riparian recovery can be herbivory by beavers or big game (Emmington and Maas 1994).

Given the practical constraints on controlling the timing, duration or frequency of foraging by ungulates, the only likely options are accepting the impacts, fencing to exclude big game or controlling the size of big game populations. Excluding big game has been successfully employed on several streams in Oregon (Beschta et al. 1991, Anderson 1994) and mitigation measures are used in Yellowstone National Park (Chadde 1989). Species-specific exclosures or cutting nurse trees to protect vegetation reproduction from big game are options but fencing to exclude elk can be difficult and expensive (USDA Forest Service, Aspen Working Group 1995).

Underburning is an effective tool to release regeneration in self-perpetuating clones such as aspen. However, there is a risk of losing significant numbers of mature trees to promote resprouting. (USDA Forest Service, Aspen Working Group 1995). Underburning is also a tool to control conifer invasion and restore balance between conifers and aspen (Tewksbury 1996).

Planting desired species to advance bank stabilization or to structure the vegetation community has also been used in many areas, although stabilization with a specific species in mind can sometimes be expensive and difficult (Swanston 1974). In southeast Alaska, a mix of reed canary grass and alder wildlings has been successfully established. In other cases, grass and other species may be seeded simply to establish cover for stability (Brown 1980). Some caution regarding the use of non-native plants is needed. Tamarisk, an aggressive exotic which is also an excellent bank stabilizer, was established in California and now ranges throughout much of the Colorado River system. It is now the target of many eradication efforts.

Technology for re-establishing native woody species like willow and cottonwood from cuttings is well developed. Cuttings can be taken at almost any time during the dormant season, but cuttings from late winter seem to be best and removal of flower buds (or selecting without buds) is desirable (Farmer 1966, Hoag 1995). Cutting, storage, and soaking techniques to enhance success are also reasonably well-documented (Krinard and Randall 1979).

Deep planting with cuttings reaching about 15 cm (6 inches) into the low water table and tall enough above the ground not to be shaded is most effective (Hoag 1995; Randall and Krinard 1977). Various augers and a "stinger" attachment for backhoes can be effective planting tools (USDA SCS 1994). Success rates have increased to 70 to 80 percent after two years for deep planting on some sites (Hoag 1995). Deep planting seems to be particularly useful in arid and semi-arid environments.

Designing planting projects on forested sites requires consideration of both tree growth and vegetation diversity (Chan et al. 1993). Growth may be important to increase the rate at which large wood becomes available, while structure is influenced by diversity. Shade tolerance is sometimes the controlling factor in the growth-diversity tradeoff. Small patch cuts and clearings can reduce competition but may also promote brush species (Emmington and Maas 1994). Partial removal is an alternative to both reduce brush competition and stimulate growth because it can reduce canopy closure and growth is directly correlated to canopy retention (Chan et al. 1993). In some systems, planting is unlikely to succeed without some form of manipulation to the overstory and understory. Additional understory treatments after the initiation of the project are also likely to be necessary to ensure growth.

Success in planting native conifers also requires attention to slope location, site conditions and species selection (Chan et al. 1993; USDI BLM 1993 and 1994). Good survival rates have been attained for western red cedar on Spencer Creek, Johnson Creek and West Fork Smith River in western Oregon, whereas success with western hemlock was poor (USDI BLM 1993; USDI BLM1994; see Box 6).

Vegetation composition in the watershed is one determinant of water availability and riparian function. Watershed studies have shown clearcut timber harvesting can increase water yields for decades and augment low flows for several years (Reiter and Beschta 1995). Entire basins with ongoing timber harvest activities may also show long-term increases in water yield based on stream flow records. Treatment by cutting or burning some non-timber tree species such as western juniper may also increase infiltration, soil retention, and water yield in riparian areas (Bedell et al. 1993). Brush control activities can also extend both the duration and amount of streamflow from the treated watershed. There is potential for improvement in streamflow that will enhance riparian vegetation below treated watersheds (DeBano et al. 1984).

Box 6
Three Year Results for Planting Native Conifers in BLM's Umpqua Resource Area in Oregon

1. Managing understory vegetation in the first season increases survival and growth of conifer seedlings.
2. Survival and growth of conifer seedlings increases when alders are girdled.
3. Of the treatments applied, managing understory vegetation and girdling 50 percent of the alders provides the best survival and growth for all species of conifer seedlings.
4. Western hemlock had the best overall performance under the experimental conditions of the study.

(Maas and Emmington 1994)

5.2 Summary for Riparian Restoration

The key to planning riparian restoration is to avoid blanket prescriptions. The stream setting and ecological site conditions need to be factored into the objectives and the design of the riparian restoration project (Chan et al. 1993). It is also important to ensure that the project addresses the underlying causes that are perpetuating declines in riparian condition.

Many projects have included features designed to accelerate progress to a desired state, in terms of function, plant composition, or habitat quality. Check dams are designed to improve pooling and promote aggradation. Willow and cottonwood plantings are intended to change plant community composition quickly. Instream structures are intended to reintroduce or simulate instream debris. These approaches have been successful under the right circumstances and with the right techniques. But there have also been high failure rates with some "accelerator" techniques such as instream structures. This suggests a thorough investigation is needed before a decision is made on which techniques to use.

Suites of coordinated actions that address riparian restoration are common. Combinations vary but they include grazing management, reforestation, road and trail closure, riparian plantings, instream structures, and facilities to direct recreation use. This may make it difficult to attribute responses in riparian condition to any single action. A number of conclusions may be drawn concerning riparian restoration:

1. Efforts to improve riparian conditions are widespread with varying results and degrees of success.

2. There is a consistent trend toward improvement on most of the riparian projects sampled, although improvement does not always occur at the same rate on different sites.

3. Indicators of improvement are consistent: increased streambank stability, decreased erosion, decreased sedimentation, narrowing and deepening of the stream channel, colder stream temperatures, and improved fish production.

4. Many of the projects address combinations of factors such as species composition, logging effects, recreation effects, impacts related to road design, and grazing effects.

5. Successful projects generally integrate an understanding of the natural and social factors such as climate, topography, soils, land use, history, compliance, and community interests with site-specific factors like stream channel gradient, riparian soils, and flow regimes.

6. Improvement occurs with management of uses, when uses are designed to ensure the system's functional needs are met.

Many restoration efforts to improve streamside vegetation, retain soils, raise water tables, improve water quality, stabilize streambanks, and improve fish habitat have clearly been successful where they have been undertaken. But with the number of miles of stream still needing attention, much needs to be done.

A list of references from the U.S. Bureau of Land Management on management techniques applicable to riparian systems is shown in Table 1.

Table 1. Technical References for Riparian and Wetland Areas with Reference Numbers (BLM National Business Center).

Riparian Area Management: A Selected Annotated Bibliography of Riparian Area Management (BLM)	TR 1737-1
Livestock Grazing on Western Riparian Areas (EPA)	P-312
Inventory and Monitoring of Riparian Areas (BLM)	TR 1737-3
Grazing Management in Riparian Areas (BLM)	TR 1737-4
Riparian and Wetland Classification Review (BLM)	TR 1737-5
Management Techniques in Riparian Areas (BLM)	TR 1737-6
Procedures for Ecological Site Inventory — With Special Reference to Riparian-Wetland Sites (BLM)	TR 1737-7
Greenline Riparian-Wetland Monitoring (BLM)	TR 1737-8
Process for Assessing Proper Functioning Condition (BLM)	TR 1737-9
The Use of Aerial Photography to Manage Riparian-Wetland Areas (BLM)	TR 1737-10
Process for Assessing Proper Functioning Condition for Lentic Riparian-Wetland Areas (BLM)	TR 1737-11
User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas	TR 1737-15

6 WETLANDS

Scenario: Wetland function has been impaired.

Wetlands areas are inundated by standing, shallow surface or ground water at a frequency and duration sufficient to support, under natural conditions, a prevalence of vegetative and aquatic life dependent on the saturated condition for growth and reproduction (Bridges et al. 1994, Manley et al. 1995). These include, but are not limited to, bogs, muskegs, marshes, swamps, estuaries, riparian areas, wet meadows, and wet forests.

Wetlands perform critical functions as natural sediment and pollution filters, providing clean water to living organisms, including humans. They are very productive areas for both plants and animals because of the abundance of water, nutrients, and minerals that sustain life, often providing critical habitats for many species. Wetlands also serve as buffer zones during storm events, reducing soil erosion and sedimentation.

At one time, wetlands accounted for about 11 percent of the total land area in the United States. This has dwindled to about 5 percent (Dahl 1990, National Research Council 1992). Reasons for reduction in wetlands are many and varied. However, agriculture and development account for a large portion of the total (Frayer 1991; National Research Council 1992). Of the remaining wetlands, many are considered degraded or nonfunctional.

Wetlands are considered degraded when one or more of the following are true:

- water quality has dropped below historic levels
- algal blooms are far in excess of expected levels
- native plant and animal communities have been altered

- hydrogeomorphic processes have been altered
- soil erosion and deposition processes have been altered.

Box 7 lists clues that can be used to quickly identify degraded wetlands.

Returning these attributes and processes to levels that provide for wetland functions, and are more consistent with their natural range of variability, is the essence of wetland restoration. To restore a wetland to proper function, the attributes of, and processes occurring in, a wetland must be well understood. Table 2 presents several wetland attributes and processes from Bridges et al. (1994). Although there are similarities in function between wetland areas, there are also many differences. Therefore, each area must be evaluated relative to its own unique capability (Bridges et al. 1994).

Succession is a natural process in any wetland. The process is generally very slow when allowed to occur at a normal rate. The state of succession represented by the wetland to be restored must be considered throughout the assessment process, and when establishing objectives or desired future conditions. It is often advantageous to consider the current balance of successional stages represented and give high priority to restoring wetlands to underrepresented stages rather than to some historical stage. In the assessment process, attributes and processes (such as those listed in Table 2) should be evaluated against both those considered "natural" for a specific wetland and against criteria for wetland function (Pritchard et al. 1994, Gebhardt et al. 1990; Clemmer 1994).

Table 2. Some Attributes and Processes for Assessing Wetland Function (Bridges et al. 1994).

Hydrogeomorphic	**Erosion/Deposition**
Ground water discharge	Shoreline stability
Permafrost	Depositional features
Continuous	
Discontinuous	**Soils**
Flood Modification	Soil type
Inundation	Distribution of aerobic and anaerobic soils
Depth	Annual pattern of soil and water states
Duration	Ponding frequency and duration
Frequency	Underlying materials
Semipermanently flooded	
Shoreline shape	**Water Quality**
	Temperature
Vegetation	pH
Community types	Dissolved solids
Community type distribution	Dissolved oxygen
Surface density	
Canopy	**Biotic Community**
Community dynamics and succession	Aquatic plant recruitment and reproduction
Recruitment and reproduction	Nutrient enrichment
Root density	
Survival	

Box 7
Visible clues to decline in wetland function

- headcutting
- evidence of sheet rill or gully erosion
- evidence of a lower water table such as surface drying
- declining populations of wetland plant species
- encroaching upland plant species
- disappearance of wetland obligate species

(Based on Zeedyk 1996)

The support and partnerships for wetland restoration efforts can often be very difficult, especially in areas where the wetland or the water is highly valued for uses other than habitat for native plants and animals. For example, in the prairie pothole region, wetland areas are very productive for agricultural uses. Resistance to "giving this land back to the birds" is quite natural. However, by showing landowners that profitable agriculture and abundant wildlife can coexist, resistance to restoration of these wetlands is eroding. See also Case Study 6.

6.1 Management Options for Wetland Restoration

Options for restoration of wetland systems are grouped into the three different approaches discussed above: structural treatments, management of land uses, and biological intervention. See also Covington et al. (this volume) for additional case histories related to salt marsh restoration in the Northeastern United States.

6.1.1 Structural Treatments

A common problem in wetland ecosystems is alteration of hydrologic flows by roads and trails. Until normal

Case Study 6. Restoration of the Everglades in South Florida

This case study provides an overview of the long-term, intensive effort in south Florida to restore the Everglades. Channelization, drainage, and filling of wetlands in the south Florida ecosystem have gradually altered the hydrologic regime, resulting in serious changes to natural communities. A large-scale program is now in place to reverse this process and restore balance to the system.

Geographic Area/Location
The south Florida ecosystem encompasses about 10,800 square miles, which includes at least eleven major physiographic provinces and a population of six million people.

Participants
National Park Service, Fish and Wildlife Service, National Biological Survey, United States Geological Survey, Bureau of Indian Affairs, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Ocean Service, Natural Resources Conservation Service, Agricultural Research Service, U.S. Army Corps of Engineers, U.S. Attorney's Office for the Southern District of Florida, and U.S. Environmental Protection Agency.

Restoration Goals
To restore and maintain a healthy, balanced and functioning estuarine and marine environment in south Florida. The result should be a system where human activities and actions occur in a manner that supports healthy natural conditions and leads to diversity and abundance of natural biological systems.

Background
Prior to the late 1800s, wetlands covered most of central and southern Florida. The landscape was characterized by swamp forest; sawgrass plains; mosaics of sawgrass, tree islands, and ponds; marl-forming prairies; wet prairies; cypress stands; pine flatwoods; pine rocklands; tropical hardwood hammocks; and oak hammocks. The estuarine-coastal system was composed of shallow seagrass beds; riverine and fringe mangrove forests; intertidal flats; coral reefs; hard bottom communities; mud banks; and shallow, open inshore waters. This system was sustained by a hydrologic system that stored and released water on a large scale over a vast area, providing diverse habitat for innumerable plants and animals.

In the late 1800s, efforts began to control and drain water in the south Florida ecosystem. The main objectives were to provide flood protection, produce more arable land, provide land for development, and protect the water supply of a growing population. A multitude of water control structures (dikes, levees, canals, and pumping stations) were built, resulting in major changes to the hydrologic flow regimes and ecosystem processes in the region. Losses in ecosystem function were coupled with overall reduction in the extent of the wetlands as land development progressed. Currently, wetland ecosystems in the region are greatly reduced in extent and highly fragmented, with poor hydrologic connectivity, reduced biodiversity, and reduced biological productivity.

Restoration of this ecosystem to pre-late 1800s conditions is impossible given current land use patterns. This restoration effort is focused on: (1) restoring proper hydrologic flows to critical habitats, (2) recovering healthy populations of plant and animal species, especially those that are threatened or endangered, (3) preventing further wetland loss, (4) recovering as much ecological structure and function as possible, (5) halting and reversing the invasion of exotic plants and animals, (6) preventing pollution, and (7) promoting water conservation and reuse in urban and agricultural areas. A detailed plan aimed at achieving this has been developed and many restoration projects are currently underway.

Results/Outcomes
The intended final result of this long-term effort is a sustainable, productive, self-maintaining system that can coexist in harmony with human needs and demands. This will not happen for some time, but progress is being made.

Reference
Jacobsen, J.M. 1994. An Analysis of Fifty Years of Success and Failure in Everglades Management. Ochopee FL: The Everglades Institute

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flow patterns are returned to the system, attempts to restore native flora and fauna will be ineffective. Restoring hydrologic function to a wetland can be tricky. If the wetland is being drained, a water impoundment structure may be needed. If the area is being inundated with water, some type of drainage structure may be needed. Surface flow problems are usually apparent, but subsurface flows may be more difficult to assess. Subsurface flows are often impeded by roads and trails as a result of compaction of subgrade material. This causes water flow imbalances across the wetland and can result in channelization.

As in the terrestrial and riparian scenarios presented above, changes in road design and maintenance can either be a threat to ecosystem function or an avenue for restoration. Zeedyk (1996) suggests potential effects are tied to road location and alignment, channel crossing location and design, drainage design, road surface materials, sediment abatement and filtration, and wildlife habitat buffers. A variety of technical treatments, including relocation to adjacent sideslopes, are available to fit most situations.

The distribution or effectiveness of water to support wetland functions can also be affected by diking diversion and topographic simplification. For example, in the Warner Wetlands in Oregon, wetlands had been leveled for agricultural use. Dikes had been placed to facilitate flood irrigation. The flow of water onto the area was also affected by a dike to augment water storage in an adjacent lake. Restoring wetland function and sustained habitat conditions required raising and constructing dikes and mounds to increase topographic relief and influence water movement (USDI BLM Lakeview 1990). Technical information on creation of wetlands has been summarized by Scheller-McDonald (1990).

Water availability is a critical, and sometimes controversial, need. In the San Luis Valley in Colorado, much current wetland habitat is supported by wells. Development of water within the valley (some proposed for transport outside the basin) affects the quantity and quality of water available for wetlands and can be complicated by political issues surrounding water rights (Cooley 1991). But the only realistic long-term solution is persistent coordination among all the parties and interests (USDI BLM, Canon City 1992) (see Case Study 7). A similar need for dependable water in the Warner Wetlands of Oregon was resolved by acquiring a water right with a land acquisition and then drilling a well (USDI BLM Lakeview 1990).

Although not intuitively obvious, wetlands do burn. Some wetlands evolved with fire as a significant disturbance regime and, therefore, need fire to maintain conditions. Suppressing fire in these wetlands will cause many changes from the "natural" state. Prescribed burns in these areas at intervals suggested by natural cycles should correct imbalances. If this is not possible for technical or social reasons, some type of vegetative treatment that mimics the effects of fire (such as mowing) might be used to get the same result.

This substitution of one attribute or process for a similar-acting one (i.e., mowing or grazing for fire) can be used whenever the appropriate relationships exist. Care must be taken to validate that the substitute attribute or process is truly interchangeable with the natural one. Examples of attributes or processes that might be substituted for natural processes in wetland restoration projects include water control devices, cultural practices (such as soil working, soil stabilization, mulching, and fertilizing), or manipulating the existing vegetation.

6.1.2 Managing Land Uses

Another common problem in wetland ecosystems is sedimentation. Sedimentation is a normal process in wetlands. Agricultural and forestry practices are often implicated in accelerating natural erosion rates. Possible solutions include using appropriate erosion control practices (culverts, water bars, broad-based dips) on lands in the watershed and leaving vegetative filter strips between wetlands and adjacent lands. See also the riparian scenario above.

Chemical loads are a serious concern in wetlands. Wetlands generally act as sinks, causing chemical concentrations to build rather than dissipate. This can affect all organisms in the wetland or only specific sensitive species. Chemicals may come from industrial, agricultural, forestry, or urban sources. Point sources are generally easier to affect than non-point sources. Eliminating the source of the contaminant is the most effective way to deal with the problem. This is often not possible, however. In some cases, adding other substances (e.g., lime to raise pH) or organisms (i.e., bacteria to break down organic chemicals) may help.

Sometimes the main factor degrading a wetland ecosystem is how it is being used. Examples include overharvest of wild rice, clams, or timber resources; recreation use by boats; or food chain disruptions by excessive hunting or trapping. The common method to address wetland uses is to regulate them to a level that can be sustained without degrading the ecosystem. Often regulation includes restricting access or imposing harsh penalties. But in other cases, seasonal limitations will accomplish the desired goals.

Exclusion of uses can sometimes be effectively combined with changing the timing and duration of the remaining use. The Bureau of Land Management found portions of the 51,000 acres of public lands in the Warner Wetlands were best managed without grazing, while grazing was compatible on others. In one segment of the management area, grazing use is designed to maintain habitat for long-billed curlews (USDI BLM Lakeview 1990). See Case Study 8.

6.1.3 Biological Intervention

One restoration technique is to intervene through seeding and planting native vegetation or reintroducing wetland species. In concept this is similar to substitution of one attribute or process for another. The appropriate conditions and relationships must exist and care must be taken not to introduce undesirable species or genetic characteristics.

Invasion of exotic plants and animals into wetland ecosystems can be destructive to native species. Depending on the type, exotics can attack native species directly or crowd them out by utilizing scarce resources. Exotics often spread rapidly, with no natural enemies to keep their populations in check. The best approach is to remove them from the system before

Case Study 7
Blanca Wetlands Area, San Luis Valley, Colorado

This case study involves re-establishment of wetland functions and coordination among restoration programs by adjacent managing agencies with similar restoration objectives. The restoration effort is an attempt to integrate a regional set of objectives for a portion of the Central Flyway. The key is getting management agencies to agree on their roles and then make a commitment to fulfil and maintain those commitments. Management decisions for Blanca Wetlands Area also deliberately incorporated social and economic factors, anticipating future demands on the area.

Geographic Area/Location
Blanca Wetlands Area covers 22,363 acres in three tracts, one of which (9,774 acres) is an Area of Critical Environmental Concern (ACEC). It is northeast of Alamosa, Colorado in a broad, high, mountain valley (about 7,500 feet) drained by the Rio Grande River. The core of the Blanca Wetlands is unique to the valley because it is not subject to riverine cycles and influences. Five different ecological sites were identified based on soil vegetation associations. Uplands of greasewood, rubber rabbitbrush, saltgrass, sandhill muhly and sand dropseed are interspersed with wetlands supporting bulrushes, cattail, spike rush, pond weed and watermilfoil. Willows, cottonwoods and hackberry trees add vertical structure.

Participants
Bureau of Land Management (BLM), Fish and Wildlife Service, Colorado Division of Wildlife, State of Colorado (Water Resources, Transportation, Parks), Bureau of Reclamation, landowners.

Restoration Goals
The goals for Blanca Wetlands are to: (1) provide a place to achieve piece of mind with an opportunity to experience an interaction between mankind and nature, (2) provide restoration of healthy sustainable wetland habitat of sufficient quality to foster viable wildlife and plant populations that will benefit and be accepted by the community, and (3) provide a mosaic of diverse sustainable upland and wetland habitat types which blend into the existing setting. The plan then incorporates specific objectives and land use allocations.

Background
Waterfowl populations in the San Luis Valley declined 50 percent in the 1960s and 1970s. The primary cause appears to be loss of habitat, particularly nesting habitat. Publicly-owned wetlands in the valley were being managed primarily by the Colorado Division of Wildlife, Fish and Wildlife Service and the Bureau of Land Management. The Blanca Wetlands (BLM) are at the lower end of the basin in an area known as the "sump" which historically had shallow playa lakes and associated wetlands. As the water table declined, these became dry.

The original BLM Habitat Management Plan was completed in 1968 after a pilot project of three artesian wells and some control dikes was completed in 1966. Since the 1960s, BLM has drilled a total of 51 wells, providing water from an underground artesian aquifer. This water was supplemented by obtaining project water from the Franklin Eddy Canal as mitigation for pumping that occurs in the Closed Basin project area. Legal water issues continue to be a major concern affecting the project.

In 1991, the Colorado Division of Wildlife, Fish and Wildlife Service, Bureau of Reclamation and BLM prepared a joint San Luis Waterbird Plan. The plan agreed to focus management efforts on 25 percent of the wetlands in the San Luis Valley, with the most intensive restoration and management efforts dedicated to 30,000 acres. The plan also presented issues and strategies for waterbird/wetland management, and set shared objectives to guide water and landscape management by the cooperating agencies. In 1992, a review of operations under the original Habitat Management Plan was conducted. In 1995, the BLM plan was updated.

Land uses include livestock grazing and recreation. Grazing by domestic livestock is not a major issue in the Blanca Wetlands. Most of the area, by agreement, is subject to grazing only when requested by BLM to enhance wetland values. The area receives limited amount of recreation use (about 4,000 visits/year), primarily for wildlife observation, sightseeing, fishing and hunting. Limited development of deeper ponds to support sport fishing has been incorporated in the restoration effort, but the objectives have focused more on the shallow emergent wetlands appropriate to the setting. Other forms of recreation are also being managed to conform to appreciation of the wetlands for what they are and to avoid conflict with natural resource objectives.

Results/Outcomes
The Blanca Wetlands Area is now recognized by the Colorado Division of Wildlife as a core waterbird production area that is necessary for recovery of the valley's nesting populations of water birds. It is providing habitat for up to 30 wintering bald eagles, as well as white faced ibis, western snowy plovers and the many stemmed spider flower (all sensitive or threatened species).

Since the mid-1980s a severe downward trend in breeding waterbird species in the San Luis Valley has reversed. Nesting pairs of geese in Blanca Wetlands have increased from 10 or fewer in the 1970s to 133 in 1994. In bird counts (by station) 52 to 73 species per wetland area were documented in 1992 and 1993. An estimated 19,000 breeding birds utilized the Blanca Wetlands in 1995.

Reference
USDI Bureau of Land Management, Final Blanca Wetlands Integrated Activity Plan/Environmental Assessment 1995; San Luis Valley Waterbird Management Plan 1991.

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Case Study 8
Warner Wetlands, Oregon

This case study included evaluation of wetland functions, identification of restoration objectives and implementation of restoration projects in the Great Basin in southeast Oregon. The restoration effort integrated structural treatments and changes in the management of land uses. Management decisions incorporated social and economic factors to help sustain local communities. Structural treatments (well, dikes, etc) were designed to compensate for historical landscape modification and water availability. While it is early, ecological trends appear to be positive.

Geographic Area/Location

Warner Wetlands is a 51,000 acre Area of Critical Environmental Concern (ACEC) designated through the BLM planning process. These remnants of a Pleistocene lake are located just northeast of Plush, Oregon in Lake County within the Warner Valley of the Great Basin physiographic province. The ACEC includes about 19,000 acres of intermingled lakes, ponds, emergent marshes, and meadows. Dunes and sagebrush, greasewood, saltbrush or saltgrass flats are interspersed with the wet areas, completing the mosaic. Annual fluctuations in runoff, as well as longer drought/wet cycles make for a dynamic landscape.

Participants

Bureau of Land Management, Ducks Unlimited, North American Wetlands Conservation Council, Oregon Department of State Lands, landowners, local residents and ranchers.

Restoration Goals

The goal for the entire ACEC is to emphasize the preservation and protection of unique wildlife, ecological, cultural and geological values. A "Core Wetland Area" of 30,400 acres is managed to improve wildlife resource values, eliminating all conflicting uses, demands and allocations. A 22,618 acre grazed area is managed to increase livestock forage production while improving the composition, vigor and density of plant communities. A 420 acre meadow is managed to provide emphasis on improving wildlife habitat condition or enhancement while providing opportunities for other uses such as recreation (sight seeing, bird watching, etc.).

Background

The Wetlands are in a closed basin and are influenced by annual precipitation and runoff. For the most part, water moves through the valley from south to north filling a series of sloughs and channels, depressions and potholes, lakes and ponds. In 1983 and 1984, high runoff brought the wetlands to historical high water levels filling all the lakes in the basin. The high water also flooded many agricultural fields and damaged irrigation dikes. By contrast, all of the valley's lakes have completely dried at least three times in history.

Hart Lake is immediately south of the ACEC. Between Hart Lake and the Warner Wetlands is a large dike which raises the level of the lake by holding back water that would spill to the north. Portions of the area north of the dike had been leveled and converted to agricultural fields. All of the public lands were grazed by livestock, primarily during the growing season before restoration activities began. The area also receives recreation use, primarily for wildlife observation, sightseeing, fishing and hunting. Numbers of nesting waterfowl and water birds were severely depressed due to extended drought and poor nesting habitat.

Completed aspects of the Warner Wetlands project include: (1) 25 miles of engineered dikes and control structures to reintroduce topographic complexity and control water flow, (2) Rebuild, repair, relocate and replace 48 water control structures, and (3) drilling of a 650 foot well (2,000 gpm). The well is located near the Hart Lake dike and is used to supplement the water supply spilling to the north. Land use changes include: (1) elimination of grazing in some areas to enhance nesting cover, (2) changes in grazing in some areas to improve vegetation trends, (3) grazing designed to meet nesting needs for long billed curlews and related species, and (4) facilities to control, direct and facilitate recreation.

The BLM raised concerns over how well the wetlands were functioning in 1987 based on nesting cover studies. A Draft amendment to their land use plan was issued in 1988, generating both interest and controversy. A working group, the District Grazing Advisory Board and the District Multiple Use Advisory Council all participated in efforts to develop a mix of management strategies to integrate wetland restoration and sustainable land uses (especially livestock grazing). One of the outcomes was to provide substitute forage in other areas to mitigate economic impacts.

Results/Outcomes

Drought during the first three years of implementation allowed projects to be completed restoring 1,293 acres of wetland and enhancing an additional 2,554 acres. Water conditions in 1993 provided for wetland habitats. The 1993 monitoring studies of 4,673 acres of wetland indicated 7,590 nesting pairs of waterfowl and 3,166 nesting water bird pairs. 1994 monitoring results showed 8,946 nesting pairs of waterfowl and 3,746 nesting water bird pairs.

Reference

USDI Bureau of Land Management, Warner Wetlands Area of Critical Environmental Concern (ACEC) Management Plan; Devaurs, Walt. 1993/1994 Completion Reports and Breeding Pair Surveys, Warner Wetlands Habitat Management Plan, Warner Valley, Oregon

Contact Persons

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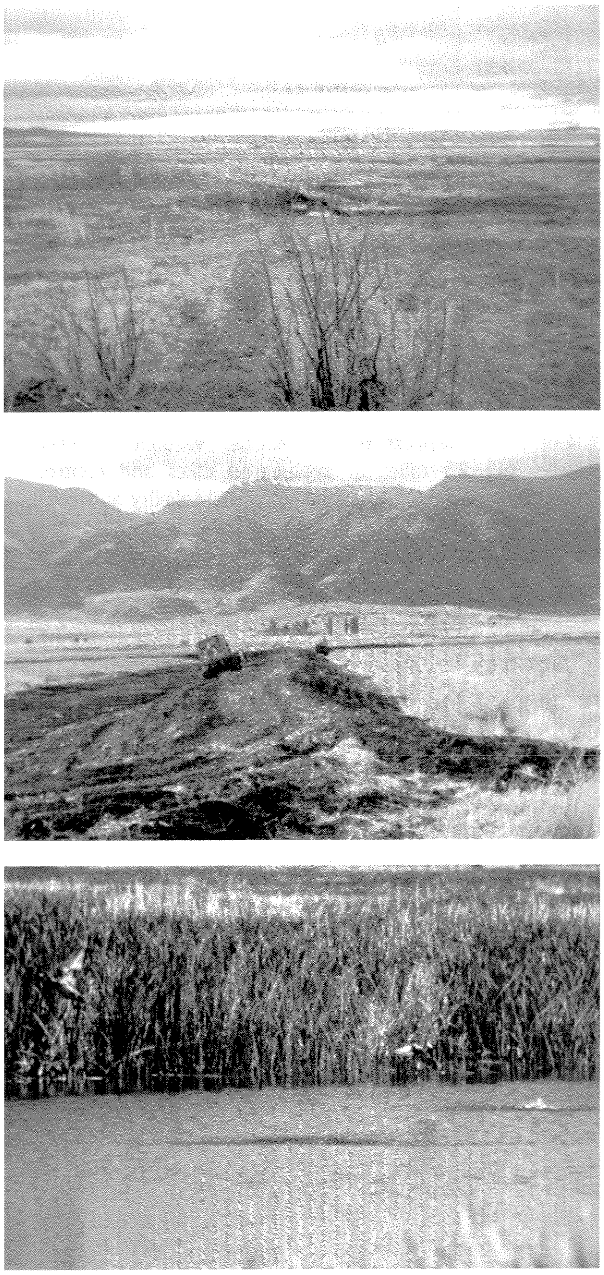

Fig. 7. *Top*: Warner Wetlands in Oregon before restoration; *middle*: re-establishing topographic variation; *bottom*: Warner Wetlands after restoration. (Photos courtesy of James Kenna.)

they spread. This requires local knowledge of exotics, constant vigilance, and a quick, aggressive response. Populations of exotics that get out of control can be difficult and costly to keep in check. Examples affecting wetlands include spruce budworm, purple loosestrife and tamarisk.

6.2 Summary for Wetland Restoration

The quantity and quality of some wetland habitats have been improved, at least at the local level, through restoration actions. Restoration efforts commonly center around returning or enhancing hydrologic function and topographic complexity.

Assessments consider all possible sources of change in the system. These may include infrastructure (such as drainage ditches, dikes, dams, levees, roads, culverts, bridges), land-use practices (such as agricultural or forestry practices that are increasing sediment and chemical loads or changing vegetation characteristics), industrial practices (such as wastewater or toxic substance release into air, water, or soil), recreational or subsistence practices (such as excessive hunting, fishing, boating, that have changed ecological balances), and other factors (such as the introduction of exotic plant species and pests, fire suppression).

Tools and techniques to restore proper function and condition to the wetland will be specific to the site and should be well correlated with their expected effects. For example, if lack of water caused by diking is a main cause of degradation, alternatives to return water to the site might include removing the dikes, providing drainage through the dikes, pumping water across the dikes, or redirecting a nearby stream into the area.

7 DRASTICALLY DISTURBED LANDS WITH FEW BIOLOGICAL LEGACIES

Scenario: Lands are degraded with limited species abundance or diversity, frequently with physical or chemical attribute problems.

Bare lands with few biological legacies are areas which were once biologically productive, but have been disturbed to the point where their biomass production and/or biological diversity are significantly impaired. In such areas, native vegetation, soil microbes and animal life have been killed or removed and most of the topsoil may have been lost, altered, or buried.

Such areas are called "drastically disturbed lands" by Box (1978). Most of these drastically disturbed lands will not completely "heal" themselves within a human lifespan through unassisted ecological processes, and, therefore, are of particular concern in land management (see Box 8). Restoration of drastically disturbed lands almost always requires the incorporation of a blend of structural, human use, and biological approaches referenced in previous sections.

7.1 Ecological Problems Associated With Drastically Disturbed Lands

The problems associated with the loss of biological productivity on drastically disturbed lands are intimate-

Box 8
Drastically Disturbed Lands that Frequently Require Restoration

- Inactive and abandoned mine lands
- Abandoned (exhausted and degraded) agricultural lands
- Abandoned roads, powerlines, transportation corridors
- Derelict industrial or construction sites and areas of urban clearance
- Areas with intense surface disturbance, such as removal of soils, dredging, disposal of solid wastes, and intense erosion
- Areas of natural catastrophes and disturbance, such as severe floods, mudslides, landslides, volcanic eruptions, intense wildfires
- Sites contaminated by industrial or agricultural wastes, chemical spills, polluted waters, or air pollution

ly associated with problems that have arisen from the degradation of physical resources: soils, water, and air. The causes of the loss of biological productivity include:

- disturbance of the land surface resulting in loss of soils, changes in soil structure, or critical changes in geomorphology that alter habitat conditions,
- disturbance of the hydrologic regime resulting in changes in water availability, quality, or flow,
- contamination of lands and waters with toxins that inhibit or limit biological productivity and
- loss of critical nutrients that support biological productivity.

For example, mining and construction activities often create large holes in the ground that are subject to flooding and erosion, altering surface and ground water flow patterns. Earth movement and the disposal of solid wastes may create steep-sided unconsolidated piles that are unstable and subject to erosion. Disturbance of the land by industrial, construction, transportation, and recreational activities may result in compaction and loss of soil structure.

Disturbed surfaces often create conditions of poor drainage or drought. Surface conditions may lead to extreme surface temperatures and erosion by water or wind. In arid areas, sporadic disturbance of soils (e.g., off-road transportation corridors) may not show significant vegetative recovery even after decades of non-disturbance (Webb et al. 1988).

Wastes spread on the surface or buried in the shallow subsurface may lack nutrients or present toxicity problems that inhibit plant growth. On contaminated sites, tolerant plants may concentrate heavy metals, radionucleotides, and other toxins in their plant tissues that ultimately sicken or poison the animal populations that feed upon them (e.g., heavy metals: Rebele et al. 1993, Cook 1981, Gough et al. 1979; selenium: Severson et al. 1991; molybdenum: Erdman et al. 1978). The disturbed surface and surface waste materials may lack soil microorganisms and animals that produce the necessary soil characteristics to increase soil fertility.

The heat of intense wildfires can kill vegetation, nearly sterilize soils, and dramatically reduce the seed reservoir. The resulting conditions significantly slow the rate of biological recovery, leading to increased erosion, sedimentation and decline in water quality (Savage 1974, Lathrop 1994). All of these effects provide an inhospitable environment for plant growth and limit biological productivity.

The ecological effects of drastically disturbed lands are not restricted to the disturbed sites. The presence of drastically disturbed lands alone can have considerable influence over a landscape because they are unsightly and detract from its beauty. The lands may also impair or limit ecosystem processes on a regional scale (see Box 9).

Erodible materials from the disturbed lands may be transported great distances during flood and storm events, changing the sediment character of riparian systems. Windblown materials can produce dust and haze, and can distribute contaminants in the form of fine particulate matter over a large area. Contaminants from acid drainage from abandoned mines can leach into streams and have significant effects on aquatic organisms downstream. See Case Study 9.

Patch effects created by disturbed lands can have undesired ecological consequences by providing suitable habitat for noxious weeds or pests that can later invade surrounding areas. For example, non-native brome grasses and other noxious weeds are common invasive species in disturbed lands throughout the

Box 9
Regional Ecosystem Processes that May Be Affected by Drastically Disturbed Lands

- Hydrologic flux and storage
- Generation and maintenance of soils
- Biological productivity
- Biogeochemical cycling and storage
- Organic matter decomposition
- Maintenance of biological diversity

Case Study 9. Restoration of abandoned mine lands in Bonanza Mining District, Colorado

This case study describes a voluntary partnership to restore the water quality of acid mine drainage and contamination from abandoned hard rock mines and mill tailings to improve stream habitat on federal and adjacent private lands. The USFS brokered a voluntary settlement among federal and state agencies with the Potentially Responsible Parties (PRPs) under CERCLA to begin cleanup activities that will reduce legal and taxpayer costs, and achieve faster results than under the standard regulatory procedures.

Geographic Area/Location

The Bonanza mining district is located at the northern end of the San Luis Valley of south-central Colorado, partially in the Rio Grande National Forest, centered around upper Kerber Creek and its tributaries and the old mining town of Bonanza.

Participants

U.S. Forest Service, U.S. Environmental Protection Agency, Agencies of the State of Colorado and PRPs.

Restoration Goals

Restoration of water quality for 10 miles of affected streams. Another USFS goal was to use CERCLA authority to obtain non-USFS funds for restoration.

Background

The Bonanza mining district includes a number of abandoned hard-rock mines, tailings piles, ore-processing mills, and drainage tunnels that were developed and worked sporadically from the late 1800s until 1969. Many owners and operators were present in the district over this time, complicating liability and legal issues. Overall production from the district was approximately 600,000 tons containing 158 tons of silver, 14,600 tons of lead, 6,800 tons of copper, 1,300 tons of zinc, and 450 pounds of gold. Many environmental problems on Federal and private land in the Kerber Creek drainage are related to pre-1931 mining activities. These problems include continuous discharge of drainage from mine tunnels, erosion of metal-rich tailings into Kerber Creek at various sites, and acidic seeps and runoff from various waste sites. Due largely to the abandoned mine sites, approximately ten miles of Kerber Creek and other drainages are devoid of fish and other aquatic fauna.

In 1991, the U.S. Forest Service formally notified the Environmental Protection Agency (EPA) of a suspected release of hazardous material on the Rio Grande National Forest-administered lands in accordance with CERCLA. In 1992, the Forest Service completed a CERCLA Preliminary Assessment and the PRP's known at the time were notified of the initiation of a CERCLA action near the town of Bonanza. They were informed of their status as PRP's and were requested to respond to a CERCLA Information Request. The Information Request sought further site information and any additional PRPs. Under CERCLA, PRPs include all current and former owners and operators of a site. Liability under CERCLA is "strict, joint, and several", meaning that PRP's, individually or collectively, are legally liable for all costs (legal, information gathering, and remediation) regardless of (1) whether they performed mining or (2) the size of any "injury" they may have directly caused.

The primary responsibility of the Forest Service is to achieve efficient and cost-effective clean-up of environmental problems on federal lands, but response on private lands was also necessary to effectively achieve restoration. The Forest Service believed the major problems needing to be addressed initially were evident, and that lengthy and costly additional study was unnecessary. The Forest Service convened a PRP meeting in 1993 to review the Bonanza Mining Area CERCLA Site situation, to encourage PRP's to form a group to jointly address issues and to discuss alternatives.

The Forest Service proposed that there were three basic options for CERCLA response actions on the site: (1) The site would be listed as a National Priority List (Superfund) site. EPA would take over both the public and private portions of the site, conduct a thorough evaluation, oversee remediation over a period of several years and would seek cost recovery from the PRPs. (2) The Forest Service would conduct studies, possibly leaving significant environmental problems for the EPA to address in due time. Both the USFS and EPA would seek cost recovery from the PRPs. (3) The PRPs would voluntarily undertake CERCLA response actions on Rio Grande National Forest lands under Forest Service CERCLA authority and oversight, and would initiate clean-up on private lands under State of Colorado permit and oversight.

The Forest Service preferred the third option, believing that it could lead to timely and effective response actions by private parties at minimal taxpayer expense. The third option offered the PRP's the best opportunity to control their costs. Option three also directed funds into actual clean-up rather than study, overhead, and legal fees. The Forest Service encouraged the PRP's to develop voluntary plans for the site areas where they had actually been involved.

As a result of the 1993 PRP meeting, the Forest Service and the State of Colorado received a proposal from the PRP's for the voluntary and public-funded clean-up of several areas within the overall CERCLA site on public and private lands. Remedial action started at the Bonanza CERCLA site in 1994 and continues to the present. More than 100,000 cubic yards of metal-rich mine tailings have been moved into a State-approved waste repository on private land. A small permanent tailings repository was built on National Forest lands to allow treatment and release of more than 150,000 gallons of acidic metal-rich mine-drainage waters that were ponded on the site. The release point of the treated water was shifted downstream to prevent possible degradation to the riparian ecosystem in the immediate vicinity. Other work included construction of a 1.6 million gallon drainage pond for surge protection from tunnel drainage, storm water control, stream channel reconstruction, and revegetation.

Results/Outcomes

The Rio Grande National Forest has successfully implemented remedial actions within the Bonanza Mining Area CERCLA site since 1994. As the lead agency, the Forest Service asserted CERCLA authority, sought PRP involvement early, and worked with all parties to remediate both federal and private land. This is the first locale where the Forest Service has enlisted private parties liable under CERCLA to conduct voluntary remediation under Forest Service authority and oversight. The geologic and climatic complexity of the site combined with point source and diffuse contamination (mine workings and waste, tailings, mill sites, drainage tunnels, and downstream transport of contaminants) make review of technical remedial plans difficult. Unexpected field conditions and weather have caused difficulties and minor delays in site actions. The need for continuous and thorough communication with stakeholder agencies and parties, such as the State and EPA, has caused some delays in site work actions.

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western United States. (See the terrestrial scenario above.) These species become well-established in both disturbed and undisturbed areas following introduction into a disturbed area (Beatley 1964). By controlling soil moisture levels, opportunistic invasive weeds, which may be at an advantage under the harsh conditions on disturbed lands, may prevent the recovery of the pre-disturbance species and displace adjacent native vegetation (Webb and Wilshire 1988).

7.2 Management Objectives, Principles, and Options

Management objectives and guiding principles for drastically disturbed lands are addressed separately below. Although there are similarities to other settings, there are also important differences.

7.2.1 Management Objectives

Management objectives for severely degraded lands include improving ecosystem processes and containing or restricting the spread of further ecosystem degradation (see Box 10). Ecological restoration as applied to drastically disturbed lands involves restoring or improving the physical conditions of a site to a point where critical ecosystem processes are operable, allowing re- establishment of plant and animal communities or a critical habitat.

Box 10
Examples of Desired Ecological Conditions to Be Achieved through Restoration

- The effects of erosion, leaching of heavy metals, toxic materials, and contaminants into and upon surrounding areas (including surface and ground water bodies) should be minimized.
- The system should be physically stable so that heavy rains or rapid snow melt will not destabilize it and cause mud slides, rock falls, and other catastrophic events that block roads or endanger human habitations.
- The restored or rehabilitated ecosystem should achieve and maintain ecological stability as quickly as possible, i.e. the systems should be self sustaining and not dependent on outside manipulation such as periodic irrigation or fertilization.
- The system should be, at best, aesthetically pleasing, and, at least, not displeasing.
- The ecosystem should be compatible with land uses and activities in surrounding areas and contribute to civic and social values as well as biological values.
- Management costs should not be prohibitive or place an excessive burden on the surrounding community so that social and financial pressures to abandon the restored systems are created.

The process of rebuilding the plant community on drastically disturbed lands usually must start from a new soil substrate. The natural ecological processes that reestablish plants and animal communities may need to be enhanced or stimulated artificially through introduction of new plant communities or by altering the conditions under which new plant communities develop.

7.2.2 Guiding Principles

The role of the land manager in dealing with drastically disturbed lands is analogous to the role of a nurse in medicine. Human health and ecological conditions are similar in that both are complex and dynamic. Both are capable of self-healing when conditions are not acute. The role of the nurse in medicine is to stabilize the medical conditions of the patient and provide conditions where self-healing can occur. Drastically disturbed lands provide a situation similar to the arrival of a patient in a hospital emergency room. Emergency action may be taken to assess the severity of the problem and to stabilize the patient. Once the patient is stabilized, other options can be evaluated. In both the medical and land management situations, the fundamental ethic guiding intervention is the same: Do no harm.

Restoration of drastically disturbed lands is experimental. The problems are complex and many situations are unique. An effective management approach is to utilize scientific principles in restoration design so that management options can be improved. Scientific principles, such as (1) the use of control areas, (2) utilizing pilot studies first, where possible, and (3) scaling actions so the results can be measured and evaluated are valuable concepts in restoration. Ecological restoration of drastically disturbed lands may involve massive human intervention that has the potential to cause unforseen and unintended consequences. Sufficient background studies are necessary to understand causes of problems well enough to evaluate whether restoration efforts are likely to be successful and to minimize the likelihood that restoration activities may result in significant undesirable physical or biological changes outside of the intended management area. See Case Study 10.

Restoration of drastically disturbed lands is site specific. Before significant intervention occurs, sufficient information should be gathered to define site-specific baseline and background conditions and set achievable restoration goals. Where possible, the use of local soils with their associated microorganisms and

Case Study 10. Evaluating remediation decisions at the Iron Mountain CERCLA site, California

This case study describes the important role geochemical research played in evaluating remediation options for an abandoned mine site where highly acidic, metal-rich drainage was impacting riparian habitat and water quality in reservoirs that supply water for area communities. Remediation of such sites often requires massive intervention with high costs, as well as complex liability and oversight issues. Additionally, many remedial actions are experimental and unanticipated results may be significant.

Geographic Area/Location

The Iron Mountain CERCLA site is located in Shasta County, California, in the Klamath Mountains near the Sacramento River, about 14 km northwest of Redding. It is partly on lands managed by the Bureau of Reclamation. Drainage from the site feeds into the Spring Creek Reservoir, Keswick Reservoir, and the Sacramento River, all of which are drinking water and agricultural irrigation sources for surrounding communities.

Participants

U.S. Environmental Protection Agency, U.S. Forest Service, Bureau of Reclamation, U.S. Geological Survey, Agencies of the State of California, Private Parties (potentially responsible parties under CERCLA).

Restoration Goals

Mitigation of acid mine drainage into the Sacramento River. Since the 1940s, more than 40 fish kills have occurred in the Sacramento River due to contamination from Iron Mountain and other nearby mines. As many as 100,000 fish (salmon and trout) died from a 3-day rainstorm event that increased metal-rich acidic drainage and remobilized metal-rich sediments in the watershed. Chronic toxicity for salmon and trout from copper, zinc, and cadmium is reported to be the highest in the United States.

Background

The Iron Mountain CERCLA site includes three abandoned hard-rock metal sulfide mines that were worked for copper, silver, gold, zinc, and pyrite from 1895 to 1962. Copper production from these mines was the largest in California and the sixth largest in the United States, estimated at about 200 million pounds. The deposits consist of disseminated and massive rock rich in sulfides, mostly pyrite (iron sulfide). When exposed to air and water, these sulfide minerals weather and produce extremely acidic and metal-rich surface and ground waters.

The mines at Iron Mountain, named the Brick Flat, Richmond, and Hornet, worked three different massive sulfide bodies. Brick Flat is the highest in elevation and was mined as an open pit for pyrite to make sulfuric acid. The largest massive sulfide body occurred in the Richmond mine, which was mined underground, and still contains about 8 million tons of pyritic sulfides. The Hornet mine, also mined underground, occurs at the lowest elevation and contains slightly less than a million tons of massive sulfides. These three sulfide ore bodies are offset and cut by faults. Groundwater can reach the sulfide bodies through faults, fractures and caved mine workings. The main portals for both the Richmond and Hornet mines served for both haulage and mine water drainage. The Richmond mine water is extremely acidic (pH of 0 to 1.1) with a discharge rate between 0.5 and 50 liters per second. The Hornet mine drainage has pH values ranging from 0.5 to 2.8 with a discharge between 0.8 and 15 liters per second. At present rates of weathering, it would take 2,000 to 3,000 years to remove the remaining sulfides at Iron Mountain.

The Iron Mountain Mine site was ranked number three on the National Priority List (Superfund) for California. In 1983, a technical advisory committee consisting of technical experts from various state and federal agencies was formed to assist the EPA in their investigations of remediation options. Many remediation alternatives were considered including no action, capping the mountain to prevent water infiltration, mine plugging, air sealing, neutralization of the acidic effluent with lime or limestone, on-site leaching and recovery of metals, surface water diversions, and increasing the size of the debris dam and catchment pond.

A proposal to renovate the subsurface workings of the Richmond mine for human access was adopted by the advisory committee. In 1990, mineral and water samples were collected from inside the underground Richmond mine workings which had not been accessible for about 35 years. The investigators found acid mine waters with pH values from 2 to 3.4 and huge growths of efflorescent soluble iron sulfate salts, formed from weathering of the massive sulfides. These then dissolve in water to form acid metal-rich solutions. Knowledge of the composition, occurrence, and volume of these salts made it possible to estimate the composition of the mine pool in the event the Richmond Mine was plugged. The salts were expected to dissolve completely under two scenarios: (1) infiltration from ground water filling the mine after plugging or (2) injection of clean water to flood the Richmond Mine workings. The efflorescent salts were thought to occupy 1–5 percent of the known volume of the workings. But since this was the most uncertain estimate of the evaluation, it was treated as a variable in the geochemical model developed by the U.S. Geological Survey to calculate the chemistry of the mine pool by simulating the dissolution of the salts. The model showed that regardless of the volume of efflorescent salts, the mine pool would have a pH of 1 or less and would contain several grams per liter of dissolved salts. Thus, there would be 0.6 million cubic meters of highly acidic mine water sitting on top of the ground water table in fracture-flow terrain and in a rock aquifer with almost no neutralizing capacity. Scientists estimated it would take 10 to 50 years for water to seep out because only about a kilometer separates the mined area from the surface along the shortest flow path. The risk from this scenario was much too great. This conclusion became a major turning point in the discussions between the EPA and the PRPs who held the liability. Since the mine workings showed a connection between the Richmond Mine and Hornet mine, the effluent from the Hornet mine was believed to be spillage from the Richmond. If this were true, plugging the Richmond mine workings would alleviate any need to treat effluent from the Hornet. However, if the Hornet mine was producing its own acid drainage, then it would require additional treatment facilities and drive up cost. While it was difficult to answer this question with existing engineering and site information, geochemical modeling proved that most of the water from the Hornet mine was produced on site and could not be leakage from the Richmond mine. The results of the geochemical modeling demonstrated the need for increasing the capacity of the water treatment facility.

Results/Outcomes

Geochemical research can be applied to site characterization and evaluation of remediation scenarios with very practical results. Research that focuses on specific remediation issues and objectives can reduce risk, reduce costs, decrease uncertainties, expand possibilities for remediation, improve performance, and avoid mistakes. The Iron Mountain Mine Superfund investigations have demonstrated the critical importance of research in answering some questions.

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seed populations, and local vegetation types, greatly aids the restoration effort.

Restoration of drastically disturbed lands can be very expensive. In situations where heavy equipment is needed for major land excavation for site reconstruction or the removal of contaminants, costs quickly escalate into the millions of dollars. It is usually more cost-effective, to treat causes instead of symptoms. Symptom intervention requires chronic maintenance and has a high likelihood of failure.

7.2.3 Management Options

Five basic management options exist for ecological restoration on drastically disturbed lands: (a) full restoration, (b) partial restoration of key ecosystem functions, (c) create alternative ecosystems, (d) containment of degradation, and (e) non-intervention with monitoring.

Under option (a), restoration attempts to return the site to its initial ecosystem state. This is a noble goal but seldom attainable in less than decades of time. Partial restoration, under option b, may be considered a pragmatic mix of rehabilitation efforts that mitigate acute problems and allow natural processes to restore the system over some interval of time.

The establishment of an alternative ecosystem under option c attempts to improve the current state of ecosystem functions, without reference to initial ecosystem conditions. Some desirable man-made features of the disturbed site may be retained or enhanced, and some natural features suppressed, because the former provide desirable and possibly unique ecosystem values to the region. Examples include:

- preservation of underground mine and adit openings in the western United States because they are utilized by bat populations as roosting sites (Frost et al. 1995),
- surface mined areas in West Virginia that have been reclaimed as grasslands to represent an ecosystem unique to that state, but similar to the Great Plains in avifaunal composition (Whitmore 1978), and
- a grassland ecosystem in Kansas that has been surface mined and replaced by a lake because the area lacked standing surface waters. The lake environment was more desirable than the initial disturbed condition and might even be regarded by some as more desirable than the initial grassland (Cairns 1983).

Other examples of alternative ecosystem options are artificial wetlands that are established to mitigate acidic and metal-rich discharge from abandoned hard-rock mine sites (Brodie et al. 1988, Dunbabin and Bowmer 1992, Eger 1994). Specific state laws and federal regulations (e.g., Surface Mining Control and Reclamation Act) may limit management options. For example, Florida state law prohibits the construction of wetlands in the phosphate mining district if there were none prior to mining, unless special waivers are obtained.

Containment of degradation under option d is a stopgap intervention intended to stabilize a site and prevent further spread of a problem. This option may be the appropriate management choice in situations where the probability of successful restoration is negligible and/or the costs of intervention greatly exceed the anticipated results and benefits. This option can be used to buy time to understand the causes of the problems on site, to pursue the research, testing, or technical development needed to assure a reasonable likelihood of restoration success, and to develop a better understanding of the probable results of restoration efforts.

The nonintervention with monitoring option (e) may be appropriate when the disturbed site is stabilized and restoration goals are likely to be achieved without intervention in a reasonable period of time or when the costs of intervention greatly exceed the anticipated results and benefits.

7.3 Summary for Restoration of Drastically Disturbed Lands

Successful restoration projects generally include some consistent management elements which are adapted and applied to fit the situation (Coats and Williams 1990: Horowitz 1990). These elements include:

1. Clear definition of biological objectives.
2. Translation of biological requirements into hydrologic and landscape conditions that need to be established on the site.
3. Good definition of site conditions.
4. Analysis of physical constraints and opportunities including consideration of surface runoff, water quality, soil characteristics and sediment transport and deposition. The site needs for flood control, erosion control, subsidence mitigation, debris management and treating toxic wastes should be evaluated.
5. Analysis of biological constraints and opportunities on site.
6. Development of restoration design alternatives that can be evaluated using quantitative computer models and empirical geomorphic relationships.

Table 3. Technical references on ecological restoration and rehabilitation of drastically disturbed lands. Listed by citation and topic/title.

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Abandoned Mine Lands

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Degraded Agricultural Lands

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Degraded Soils

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Arid Lands

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Fisher and Munshower, 1991, Selenium Issues in Drastically Disturbed Land Reclamation Planning in Arid and Semi-Arid Environments

Goudie (ed), 1990, Techniques for Desert Reclamation

Gough and Severson, 1995, Mine-land Reclamation: the fate of trace elements in arid areas

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Webb and Wilshire (eds), 1983, Human Impacts and Management in Arid Regions

Contaminated Land

Cairney (ed.), 1987, Reclaiming Contaminated Land

Gough, Shacklette, and Case, 1979, Element Concentrations toxic to Plants, Animals, and Man

Logan, 1992, Reclamation of Chemically Degraded Land

Ross (ed.), 1994, Toxic Metals in Soil–Plant Systems

Natural Catastrophes (volcanic eruptions)

Collins and Dunne, 1988, Effects of Forest Land Management and Revegetation after the Eruption of Mt. St. Helens

Cook, Barron, Papendickk, and Williams, 1981, Impact on Agriculture of the Mount St. Helens Eruption

Okamura, 1985, (translated title) A Study of Revegetation Methods for Erosion Control in Active Volcanoes

The models need to be calibrated and verified with field data.

7. Review of restoration plans and specifications by a technical review team, including important members of the restoration design team.
8. Site inspection by members of the restoration design team during construction of the restoration project. Design changes proposed during the construction phase should receive approval from the design team.
9. Management of the restoration site to promote successful germination and growth of introduced vegetation. This may include special ground preparation before planting, and use of seedling protection devices, when cost-effective.
10. Post restoration monitoring of both biological and hydrologic parameters.

Because restoration of drastically disturbed lands can be expensive, it is important to follow a fairly rigorous process in the design, implementation, and monitoring of restoration actions. It is possible to spend large amounts of money on actions that produce disappointing results. There may be situations where it is appropriate to short-cut or dismiss some steps to avoid getting caught up in review processes where similar circumstances and conditions have been successfully addressed before. But money is generally well spent when it is dedicated to understanding the site and designing actions with a high probability for success.

Table 3 contains a partial listing of technical references for further reading related to ecological restoration and rehabilitation of drastically disturbed lands organized by category of restoration. Full citations are found in the bibliography. Special attention is given to references pertaining to restoration of abandoned mine lands because they represent the largest number of drastically disturbed sites and the largest acreage of drastically disturbed lands that are managed by federal agencies in the United States (Paone et al. 1978).

8 CONCLUSIONS

Restoration is inherently an adaptive process (see Bormann et al., Volume III). Data gathering and analysis alternate with decision and action, guided by goals and objectives. Practitioners revise their thinking based on observation. Sometimes, the goal may need to change if it is unrealistic.

While ecosystem assessments may begin with single resource values and species, the complex interactions and relationships among all the social and biological components eventually surface. To meet this challenge, the most successful approaches actively seek to integrate information from multiple sources. Sometimes direct involvement from research scientists can be secured, so testable hypotheses and experimental designs can be developed and implemented that eventually expand knowledge of restoration (see, for example, Jordan et al. 1987).

Deciding where and when to do restoration can be a complex decision. Most begin with their understanding of levels of ecological function across a landscape and then consider what kinds of beneficial results and risks might be expected over time with various levels of action and investment. Frequently the most difficult aspect of the formulating a restoration decision is establishing sufficient public support to act. This is primarily because conservation values are defined by individuals who perceive the social, economic and ecological aspects of the situation differently. The most common approach is to struggle through the communication necessary to develop shared concepts of conservation value (see Fig. 8).

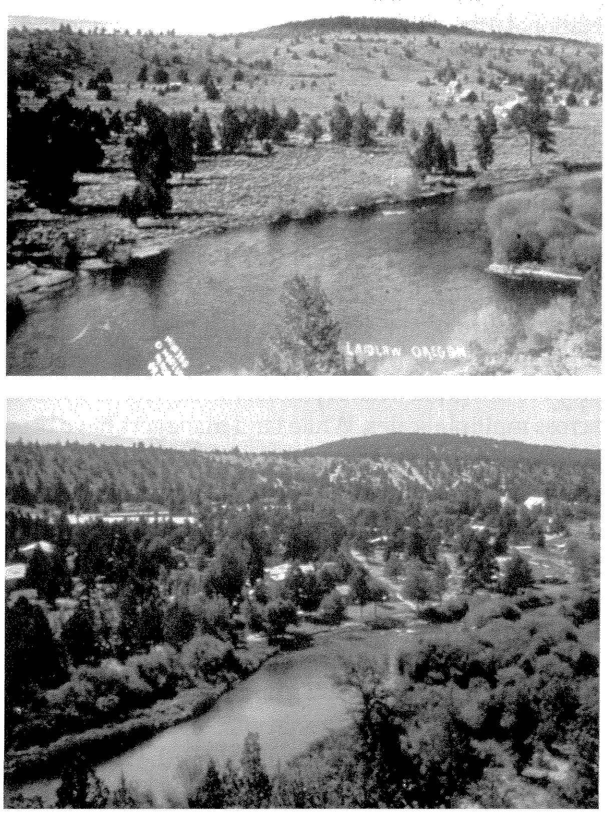

Fig. 8. Ecosystems can change dramatically due to human activities. This scheme compares the Deschutes River in central Oregon before fire control in approximately 1910 (*top*). The contemporary scene (*bottom*) features a different landscape where fire has been controlled and many homes built. Which landscape do people prefer? (Photos courtesy of James Kenna.)

Any restoration proposal must also be related to events and trends in the area because there may be limiting factors that will affect the success of the project. The final step is to evaluate options based on cost effectiveness. Cost effectiveness relates all the other factors (ecological function, benefits, risks, values, other actions/trends) and to practical considerations like feasibility and affordability.

When you combine the complexity of ecological systems with the complexity of restoration decision making, it is easy to understand why descriptions of "desired future conditions" can be a reference, but not a rigid set of expected outcomes. Rigid expectations presume precise controls and knowledge of the ecosystem that we do not possess. It is better to focus on the degree and direction of change in ecological function.

Examples of restoration on federal lands include work underway in the Strawberry Valley of Utah (Frandsen 1995), the Sierra Nevada of California (Parsons 1995; Parsons 1991; Linquist and Bowie 1988), the South Fork of the Salmon River in Idaho (Megahan et al. 1992), the Blue Mountains in Oregon (USDA Forest Service, Pacific Northwest Region 1992), Sequoia National Park (Parsons 1990, fire in mixed conifers), Redwood National Park (Spreiter 1992), the Rocky Mountains of Colorado (USDI BLM, Colorado State Office 1990), BLM land in Utah (Platts and Nelson 1985, Big Creek; McArthur and Sanderson 1996, Mojave Desert restoration) and jointly with ranches in Montana (Massman 1995). Many others are also referenced in this chapter.

The practice of restoration is really an exercise in complex problem-solving with an emphasis on the processes and functions in the system. Managers attempt to integrate what is possible with what is desired, across multiple scales. While land managers have been able to accomplish restoration on a site-by-site, or even species-specific, basis for years, some of these efforts have not addressed interactions at larger scales.

Restoration requires continuous learning because new and better information will always become available. But it is important not to become too timid, because some of the most important innovations in restoration come from experimentation. Considerable information is also already available covering techniques that have been successfully applied. Where action is better than inaction, the trick is to devise a practical combination of study, monitoring, and action.

This review encountered consistent signs of success and common characteristics of successful restoration projects (see Box 11). Because restoration is a long-term experiment in a complex system, success may not only be difficult to achieve, but also difficult to clearly demonstrate. Given the complex matrix of events and relationships acting in ecosystems, land managers and their partners need the flexibility to learn from observation, adapting actions and expectations based on system responses. For this reason, some level of monitoring from baseline conditions becomes essential to understanding outcomes and trends.

Federal land managers initiate restoration projects for many reasons, sometimes even to protect human health, or to avoid forcing legally-ordered actions. More often, the impetus is concern over the decline of a species, water quality, fire hazard, or risks to valuable plants, animals or biotic communities. The drive to restore lands and water is founded in the human desire for environmental, spiritual, aesthetic, and economic health. The translation of this desire into action can generate conflicts and choices that range from relatively simple to extremely complex, so it takes a good deal of knowledge and analysis to make restoration decisions. But even more important, it takes commitment to partnerships with affected interests and integration of multiple perspectives.

Box 11
Characteristics of Successful Restoration Projects

- Projects organized around clear objectives designed to work with ecosystem processes and functions. A solid understanding of site conditions and trends is necessary. The depth and detail of necessary monitoring and studies will vary depending on the site and the nature of the problems.
- Integration of physical and biological factors with social and economic considerations during both design and implementation.
- Expectations and monitoring that emphasize the degree and direction of change, rather than a precise set of pre-determined characteristics. Forcing systems to respond faster is not always desirable or possible.
- Consideration of the relationships between ecosystem functions and matrix of actions and conditions affecting species composition, land uses, and physical structures and processes.
- A realistic assessment of physical, fiscal and other constraints. Frequency of expected maintenance efforts to ensure a projects success is an important design factor.
- An interdisciplinary technical team, as well as coordination with constituents in both design and implementation.
- Attention to detail concerning techniques and timing during implementation relative to objectives. Sometimes, not all the variables are controllable (e.g. precipitation after prescribed burning).
- Post restoration monitoring at some level to determine trends and allow for future management adjustments.

Federal land managers and their partners operate across the full range of landscapes and restoration is becoming a major component of public land management. Although the scope and scale of the work to be done is daunting, the number of successes and the quality and intensity of the efforts which are underway are both encouraging.

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APPENDIX A: RESTORATION CHECKLISTS

The purpose of checklists is to bring order to the decision-making and data-gathering processes so that the methods and information presently available can be utilized and deficiencies in the science can be identified. Apfelbaum and Chapman (1994) provide a ten step checklist for successful restoration. Their list is presented below with some modifications.

1. Inventory and map the ecological resources, and describe their condition.

2. Describe the site's history and map it where possible.
3. Develop a hypothesis of how the original system worked. Review technical literature for related ecological studies conducted in the region; visit nearby areas.
4. Develop goals and objectives for each management unit by assessing the potential for restoration with reasonable effort.
5. Develop an implementation plan of actions and costs to accomplish the goals and objectives.
6. Design a monitoring program to evaluate success.
7. Implement the restoration actions.
8. Document results.
9. Evaluate periodically, incorporating new information and ideas, revising goals and objectives as necessary, and modifying actions.
10. Communicate constantly with interested and affected people, providing information as it is available. The Applegate Adaptive Management Area "Learning Summaries" provide an excellent model (USDI BLM, 1997)

The checklist approach of Cairns (1983) is also presented with some modifications to assist the selection of management options for the ecological restoration. These checklists are a series of questions that the manager should be able to answer; the lists should be evaluated and modified as needed to be appropriate for both specific sites and general use by the land management agencies.

Checklist for selection of management options (modified from Cairns, 1983)

The purpose of this checklist is to ensure that adequate data are available before a decision is made:

1. Can any options be excluded because of low probability of success?
2. Is the cost of any option (including cost to society) prohibitive?
3. What time will be required to reach each of the goals?
4. Is further disturbance likely to occur on site?
5. Can the management responsibilities and/or costs be transferred to another group? If so, should this be done?
6. Which option conforms most closely to existing regulatory requirements?
7. What are the comparative costs for monitoring performance?
8. Is cooperation with third parties or stakeholders possible?

Option 1: Full Restoration Checklist

1. Is restoration to a pre-existing or reference condition feasible?
2. Is adequate ecological information available about the pre-existing or reference condition?
3. Is a reference (control) site available?
4. Is the source of original species adequate ?
5. Are management responsibilities (including performance monitoring), cost estimates and duration described?
6. Was the pre-existing or reference ecosystem of local, regional, or national importance? Can societal response to this option be evaluated accordingly?
7. Is there an alternative ecosystem or land use other than the pre-existing or reference condition that is legally permissible and that should be evaluated?

"Full" restoration should be selected: (a) for ecologically unique ecosystems, (b) for aesthetic reasons where the damaged area is part of a larger system of major recreational or ecological value, (c) as a precondition for surface disturbance in unique and irreplaceable ecosystems. This option requires that substantial information about pre-existing ecosystem conditions, as well as how the location fits within the range of variability for the ecological site.

Option 2: Partial restoration checklist

1. Have the desirable parameters or ecological conditions to be restored been explicitly stated?
2. Is there evidence that the site can be rehabilitated without restoring the entire ecosystem to a pre-existing or reference condition?
3. Will the mix of parameters and conditions be ecologically stable? If not, what additional qualities must be added to achieve stability?
4. Is there a significant difference in cost between partial restoration and restoring the ecosystem to its pre-existing or reference condition?

Option 3: Alternative Ecosystems checklist

1. Have the specifications of the alternative ecosystem been explicitly stated?
2. If long-term management is required, who pays for it?

3. What is the likelihood that restoration activities may result in significant undesirable physical or biological changes outside of the intended management area?
4. Is monitoring for potential adverse effects outside of the site boundary required?
5. Is this alternative ecosystem partly or entirely experimental? If so, do the appropriate regulatory and civic authorities know this?
6. If several alternative ecosystems might be established, have the options been discussed with appropriate decision makers?
7. Is there community and stakeholder approval for the proposed actions and associated costs?

Option 4: Containment option checklist

1. Can the adverse ecological effects expected from the site be mitigated? How long should they last?
2. Is chronic maintenance of the containment strategy required? At what cost?
3. Are there any adverse health or safety considerations which threaten the general public?
4. Is the likelihood of successfully implementing other restoration options sufficiently low that containment is the most feasible short term management option?
5. How should be appropriate regulatory agencies be informed of the rationale for this decision?
6. Is there community and stakeholder approval for the proposed actions and associated costs?

Option 5: Non-intervention with monitoring

1. Is substantive evidence available that natural processes will be more effective than available management practices?
2. Are restoration goals likely to be achieved without intervention in a reasonable period of time?
3. Do the costs of intervention greatly exceed anticipated benefits and results?
4. Can any adverse environmental effects expected from the site be mitigated?
5. Are monitoring objectives and parameters explicitly defined?
6. How should the public and appropriate regulatory agencies be informed of the rationale for this decision?
7. How soon should the management options for the site be evaluated? What additional information is needed to assist this reevaluation of options?

APPENDIX B: DATA REPOSITORIES

Data Repositories: The following are general repositories of information that may be useful for ecological restoration projects. Local sources, such as district or regional offices of the U.S. Geological Survey, U.S. Forest Service, Bureau of Land Management, U.S. Natural Resource Conservation Service, U.S. Army Corps of Engineers, state geological surveys, or offices of the state climatologists may also possess useful data. The Earth Science Information Centers (ESIC) of the U.S. Geological Survey (listed below) can provide information about air photos, remote sensing data, maps, cartographic, and geographic data from many public and private producers in the United States using automated catalog systems for information retrieval and research services; for further information, call 1-800-USA-MAPS. Some academic departments within the state land grant colleges and universities have research reports, master's theses, doctoral dissertations, and extension service reports that are often very site specific.

Master Title Plats (Official Status and Historical Indices)

Official land records for the United States are maintained by all Bureau of Land Management state and district offices for the state(s) or districts they cover. Local county, U.S. Forest Service, Natural Resource Conservation Service, U.S. Fish and Wildlife Service, National Park Service and other agency offices also frequently maintain land status maps.

Aerial Photography, Remote Sensing Data

Aerial Photography Field Office, USDA-NRCS, 2222 West 2300 South, P.O. Box 30010, Salt Lake City, UT 84125

Sioux Falls Earth Science Information Center, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198-0001, 605-594-6151; Fax 605-594-6589, TDD 605-594-6933 (Telecommunications for the Deaf)

Reston Earth Science Information Center, U.S. Geological Survey, 507 National Center, Reston, VA 22092, 703-648-6045; Fax 703-648-5548, TDD 703-648-4119 (Telecommunications for the Deaf)

For a detailed description of data available from these and other local services, see: Earth Science Information from the U.S. Geological Survey, U.S. Geological Survey Fact Sheet FS 125-95. Information on these and other USGS products and services is available 24-hours a day from the EARTHFAX fax-on-demand system (Dial 703-648-4888). Product information and select digital cartographic files are available on the Internet through a World Wide Web server. The USGS home page can be accessed using browse tools, such as Mosaic, at URL:http://www.sugs.gov/

Geologic Maps

Lakewood Earth Science Information Center, U.S. Geological Survey, Box 25046, Building 810, Denver Federal Center, MS 504, Denver, CO 80225-0046, 303-202-4200; Fax 303-202-4188, or call 1-800-USA-MAPS for further information and other USGS ESIC locations

The USGS Earth Science Information Centers (ESIC) can provide information on sources of geologic and other maps from State offices of geology or conservation, State highway departments, chambers of commerce, and university and public libraries. Address listings of commercial map resources, Earth Science Information Center (ESIC) State Offices, and U.S. Geological Survey map depositories are available from the USGS ESIC's upon request.

Hydrologic Data

National Water Data Exchange (NAWDEX): The National Water Data Exchange of the U.S. Geological Survey maintains a computer data system that identifies sources of water data. The NAWDEX Office assists data users in locating sources of water data, identifying sites at which data have been collected, and obtaining specific data.

National Water Data Exchange (NAWDEX), U.S. Geological Survey, 421 National Center, Reston, VA 22092, 703-648-6848; Fax 703-648-5704

National Water Information Clearinghouse (NWIC): The National Water Information Clearinghouse of the U.S. Geological Survey disseminates information on water resources to government agencies, the private sector, and the general public.

National Water Information Clearinghouse, U.S. Geological Survey, 423 National Center, Reston, VA 22092, 1-800-H2O-9000 (1-800-426-9000)

Land Use, Land Covering, and Associated Maps

See USGS Earth Science Information Center sources listed under *Aerial Photography, Remote Sensing Data.* Many local county, Bureau of Land Management and Forest Service offices also maintain land use maps and GIS products.

Meteorologic, Weather, and Climate Data

National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, U.S. Department of Commerce, Federal Building, Asheville, NC 28801

Soil Characteristics Data

U.S. Department of Agriculture, National Resource Conservation Service, Washington, D.C. 20013

Soil maps are prepared on a county basis and contain a wealth of information but are not available for all counties. The Natural Resource Conservation Service maintains an office in each state and usually several field offices as well. These can be located through telephone directories under the heading for U.S. Department of Agriculture.

Topographic Maps

See sources listed under *Geologic Maps.*

Riparian and Wetland Technical References

National Business Center, Printed Materials Distribution Section (BC-650B), Bureau of Land Management, Denver Federal Center, Building 50, P.O. Box 25047, Denver, Colorado 80225-0047

National Wetlands Inventory Maps

U.S. Fish and Wildlife Service: Local offices of the U.S. Fish and Wildlife Service, Bureau of Land Management, U.S. Forest Service and Natural Resource Conservation Service also frequently maintain copies of these maps.

Compilations of Riparian Case Studies

See Natural Resource Law Center 1996; Massman 1995; Callaham 1990; USDI Bureau of Land Management, Colorado State Office 1990; Greswell et al 1989: USGAO 1988. Full citations are in Literature Cited.

APPENDIX C: NATIVE PLANT SUPPLIERS

The following is a 1997 sampling of commercial and other sources of native and wetland plant supplies that may be useful for ecological restoration projects. Local sources, such as local Natural Resource Conservation Districts, U.S. Fish and Wildlife, Forest Service, Bureau of Land Management, native plant societies, arboretums, etc. may also be able to provide biological supplies for restoration projects. A listing of botanical clubs and native plant societies of the United States is given in Walker (1986). Care should be taken concerning genetic and environmental variability as well as seed quality when selecting a seed source (Eddleman 1997, Pyke and Borman 1993).

Arkansas Valley Seeds Inc., 4625 Colorado Blvd., P.O. Box 16052, Denver, CO 80216

Comstock Seed, 8520 W. 4th Street, Reno, NV 89523

Country Wetlands Nursery, LTD, Box 126, Muskego, WI 53150

Environmental Concern Inc., P.O. Box P, St. Michaels, MD 21663

Fern Hill Farm, Route 3, Box 305, Greenville, AL 36037
Gardens of the Blue Ridge, P.O. Box 10, Pineola, NC 28662
Goble Seed Company, P.O. Box 203, Gunnison, CO 84634
Gooding Seed Company, P.O. Box 57, 103 Main Street, Gooding, ID 83330
Granite Seed, 1697 W. 2100 N., Lehi, UT 84043
Grassland West Company, P.O. Box 489, Clarkston, WA 99403
Horizon Seed Co., 1540 Cornhusker Highway, Lincoln, NB 68500
Horticultural Systems, Inc., P.O. Box 70, Parrish, FL 33564
Idaho Grimm Growers, P.O. Box 276, Blackfoot, ID 83221
Intermountain Seed Company, P.O. Box 62, 445 S. 100 E., Ephraim, UT 84627
Kesters Wild Game Food Nurseries, Inc., P.O. Box V, Omro, WI 54963
Lilypons Water Gardens, Lilypons, MD 21717
The National Wildflower Research Center, Austin Texas (512-929-3600)
Mangelsdorf Seed Co., P.O. Box 327, St. Louis, MO 63166
Mangrove Systems, Inc., 504 S. Brevard Avenue, Tampa, FL 33606
Maple Leaf Industries, Inc. P.O. Box 9-6, 480 S. 50 E., Ephraim, UT 84627
Maughn Seed Company, P.O. Box 72, Manti, UT 84642-0072
North American Revegetation, 1987 Crittenden Loop NW, Albany, OR 97321
The Theodore Payne Foundation, 10459 Tuxford Street, Sun Valley, CA 91352
Plants of the Wild, Box 855, Tekoa, WA 99033
Plummer Seed Company, Inc. P.O. Box 70, Ephraim, UT 84627
Ranier Seeds, Inc. P.O. Box 1549, Port Orchard, WA 98366
San Francisco Bay Marine Research Center, 8 Middle Road, Lafayette, CA 94549
F.W. Schumacher Co., Inc., 36 Spring Hill Road, Sandwich, MA 02563-1023
Sharp Bros. Seed Co., Healy, KS 67850
Siskiyou Rare Plant Nursery, 2825 Cummings Road, Medford, OR 97501
Slocum Water Gardens, 1101 Cypress Gardens Road, Winter Haven, FL 33880
Southern States Coop., 6606 West Broad, P.O. Box 26234, Richmond, VA
Southwest Seed, Inc. 13260 County Road 29, Dolores, CO 81323
Stanford Seed Co., 809 N. Bethlehem Pike, Spring House, PA 19477
Stevenson Intermountain Seed, P.O. Box 2, 488 S. 100 East, Ephriam, UT 84627
Stock Seed Farms, Inc., R.R. Box 112, Murdock, NB 68407
Westland Seed Inc. 1308 Round Butte Road West, Ronan, MT 59864
Wheatland Seed, P.O. Box 513, Brigham City, UT 84302
William Tricker, Inc., 74 Allendale Avenue, Saddle River, NJ 07458
Wind River Seed, Route 1, P.O. Box 97, 3075 Lane 51 2, Manderson, WY 82432
Van Ness Water Gardens, 2460 Euclid Avenue, Upland, CA 91768
Wildlife Nurseries, P.O. Box 2724, Oshkosh, WI 54901

Collecting seed from sites adjacent to the area to be restored has also been employed in restoration. For additional information related to restoration on Mojave and Sonoran desert lands, visit the Desert Lands Restoration Task Force web page at www.serg.sdsu.edu.

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