Watershed Restoration in the Sierra Nevada

By

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EXECUTIVE SUMMARY

The Sierra Nevada has long been important to California's economy. In the distant past, it was the commodities—such as minerals, timber, and beef—derived from the region's mines, forests, and rangelands that underwrote growth in jobs, incomes, and the standards of living for Californians, both local residents and those living further afield. Now, however, things have changed. Today, the Sierra Nevada makes even larger contributions to California's economy, but these arise not from the region's ability to produce commodities. Instead, they come from what economists call ecological services: the interaction of the Sierra Nevada's physical, biological, and climatological characteristics to provide clean water, healthy forests, attractive landscapes, and other attributes of a high quality of life for residents and visitors.

Watersheds play a special role in the Sierra Nevada's ability to provide many of the most valuable ecological services. Water serves as the lifeblood for the entire ecosystem, and its streams and rivers as the arteries and veins. Just as a blood test reveals much about a person's overall health, the quality of streams and rivers reveals the vital signs regarding the ecological health of the Sierra Nevada.

The vital signs are not good. Throughout the Sierra Nevada, water quality is degraded, native aquatic species are declining, and the natural ability of watersheds to accommodate and modulate extreme events, such as floods and droughts, has been diminished. Further declines in watershed health can be expected unless a widespread, systematic, scientifically-based program of watershed restoration is initiated soon and across the Sierran landscape.

This report summarizes the results from the first step in a multi-year effort by the Pacific Rivers Council to tie together the findings from past and on-going scientific assessments of watershed degradation, identify appropriate restoration programs, and design effective strategies for implementing and sustaining these programs. The report's first two chapters present findings regarding the principal causes and major consequences of watershed degradation in the Sierra Nevada. Chapters 3-5 describe how implementation of a watershed-specific restoration program would affect the area's economy. Chapter 6 describes the next steps that must be taken to bring about increased, reliable funding for watershed restoration in the Sierra Nevada.

Principal Causes of Watershed Degradation in the Sierra Nevada

The four most widespread activities in the Sierra that continue to contribute to declining watershed health are:

- *Livestock grazing* has caused severe, widespread, long-lasting damage to soils, vegetation, riparian areas, streams, and embedded biota in the Sierra Nevada. Although grazing pressure has declined over the past couple of decades, current grazing continues to stymie the natural recovery of riparian and aquatic resources throughout the Sierra Nevada, and grazing currently affects more acres of public land in the Sierra Nevada than any other land use.

- *Roads* damage water quality, riparian areas, the quantity and timing of water flows, aquatic and riparian flora and fauna, and the overall hydrologic and ecological functions of watersheds.

- *Logging* has contributed to degradation of water quality, riparian areas, soils, vegetation, and aquatic resources.

- *Dams and diversions*, which number in the thousands, intercept and bisect the waterways of the Sierra Nevada, altering flow regimes, blocking fish passage, and accumulating sediment. According to a regional scientific assessment, dams are the foremost cause of riparian degradation in the Sierra foothills.

Major Consequences of Watershed Degradation

As human activities erode the natural web of interactions among climate, landforms, flora, and fauna, the ability of Sierran watersheds to produce socially and economically valuable ecological services deteriorates. The following four consequences are indicative of a wider range of undesirable outcomes that would be reversed by scientifically-sound programs of watershed restoration:

- *Elevated sedimentation* accelerates the loss of reservoir storage and reduces the ability of dams and reservoirs to generate electricity, provide limited flood control, or provide water supplies for agriculture, industry, and domestic consumption. Accelerated sedimentation is associated with serious declines in riparian and aquatic habitat quality and quantity, and contributes substantially to the regionwide pattern of species endangerment.

- *Degraded soils* diminish the biological productivity and water-retention capacity of large areas, thereby impacting riparian and upland vegetative communities, increasing peak streamflows during the winter and spring, and potentially reducing base-level streamflows during the summer and autumn.

- *Degraded riparian areas* along stream banks, which are the most altered and degraded habitat type in the Sierra Nevada, contribute to deterioration in water quality, declines in the populations of some bird, amphibian and fish species, and the spread of noxious weeds.

- *Altered streamflows* resulting from land-use practices, dams, and diversions have significantly altered the ecological functions of watersheds and contributed to the demise of many aquatic resources by blocking fish passage, altering the conditions of stream channels and water quality, severely disrupting flow regimes, and inundating large areas of riverine and riparian habitats.

Watershed-Restoration Strategy: First, Do No Harm

To be truly and lastingly effective, watershed restoration requires that the causes of degradation—rather than the symptoms—be fully addressed. The avoidance of damage is far more ecologically effective, and biologically and financially efficient, than attempting to reverse or reduce impacts after the fact.

Fortunately, some watershed damage can be restored simply by suspending the activities that are causing degradation and allowing natural processes to reestablish themselves. Aquatic scientists call this "passive restoration." In other cases, the restoration of watersheds and aquatic resources requires intervention to restore watershed condition and function. This approach has been termed "active restoration." Examples of both approaches are listed below:

Grazing. Suspend all grazing in critical areas. These include *degraded areas* (e.g., riparian areas with bank stability problems, incised channels, elevated water temperatures, minimal shading, or high levels of sedimentation), *key habitats* (habitats for threatened, endangered or sensitive species), and *areas where grazing is clearly incompatible with habitat recovery*. Grazing should be allowed only where annual monitoring indicates that recovery of riparian and aquatic attributes in grazed areas is as rapid as in ungrazed exclosures.

Roads. Cease new road construction and most reconstruction, and take steps to close and decommission or relocate roads in the following sensitive areas:

- Biologically important watersheds with already high road densities (>1 mi/mi^2).
- Aquatic emphasis areas.
- Watersheds that contain or feed into habitats with threatened, endangered, depressed, or declining salmonids, amphibians, and other threatened aquatic species.
- Roadless areas > 1000 acres or smaller areas adjoining wilderness or other roadless areas.
- Biologically important watersheds with existing sedimentation or peakflow/flooding problems.
- Biologically important watersheds with significant hydrologic, mass failure, or other problems.

Additionally, all native surface roads that remain open should be rocked or graveled within two years and surveyed within one year for the need to improve road drainage and to replace stream crossings that are blocking fish passage and/or are inadequate to pass at least the flow and associated sediment load from a 100-year event. All roads that cannot have such crossings replaced within five years should be closed, abandoned, and decommissioned.

All remaining open roads should be surveyed to determine maintenance needs, including rerouting road runoff away from streams and stream crossings, and other maintenance needs. Identified maintenance needs should be implemented within two years of the survey, or the roads should be closed, abandoned, and eventually decommissioned. Surveys also should identify collector and arterial roads causing high levels of stream damage and, where appropriate, these should be relocated to less damaging areas. All roads that remain open should have a high degree and frequency of maintenance to reduce adverse watershed impacts.

Logging. Cease logging in areas where there is a high risk that it will thwart the recovery of aquatic resources or increase existing levels of degradation. Such areas include:

- Riparian areas.
- Roadless areas > 1000 acres.
- Aquatic emphasis areas.
- Watersheds with habitat for at-risk aquatic biota.
- Biologically important watersheds with already high levels of logging and/or roads.
- Biologically important watersheds with sedimentation problems.
- Watersheds sensitive to disturbance.

This may seem to be a formidable list, but in reality these special, overlapping areas provide a disproportionate percentage of services for humans and the overall ecosystem alike (e.g., habitat for endangered trout and the highest water quality). Additionally, ceasing logging in these areas would not affect the projected acreage available for commercial timber harvests, according to U.S. Forest Service estimations.

Where logging is allowed, it should not entail road construction and reconstruction. Thinning and other logging-related activities intended to reduce the amount of fuel susceptible to wildfires should be limited to urban-wildland interface areas where they would have the greatest impact on reducing the fire risk to person and property, but they should not be undertaken in riparian areas or other sensitive aquatic areas. Small, experimental fuel treatments may be planned in other non-sensitive areas if extensively monitored over time.

Dams and diversions. Prohibit the construction of additional dams and diversions. Existing facilities should be operated to reduce the amount of water stored and diverted from stream channels, so that streamflows return as near as possible to natural levels. Pilot projects should be initiated to design and implement methods for removing dams generating few, if any, economic benefits, and to convey sediment past remaining dams.

Economic Consequences of Watershed Restoration on Federal Lands

The proposed watershed-restoration measures, which would arrest the ongoing degradation of watersheds and restore their ability to produce clean water and other ecological services, would have both negative and positive impacts on the economy. The negative impacts would materialize as resource managers incur costs to design and implement a scientifically-sound, watershed-restoration program for the Sierra Nevada, and as this program curtails watershed-damaging activities of ranchers, road users, timber companies, and the operators of dams and diversions. Experience with similar efforts indicates that the actual costs are almost always far less than perceived. Part of the implementation strategy would include working with affected communities to develop ways of minimizing the costs and capturing the economic benefits of a watershed-restoration program, such as retraining displaced workers for new restoration jobs.

In general, the benefits of restoration tend to be only partially understood and the potential beneficiaries often either overlook them entirely or see them as insufficiently important to warrant strong advocacy for the watershed program. Hence, a major objective of this report is to set the stage for further efforts to quantify the benefits and to demonstrate their importance to potential beneficiaries. Preliminary evidence suggests that the watershed-restoration measures described in this report would generate substantial economic benefits, including, but not limited to, these:

- **Workers**: more jobs in industries benefiting from higher levels of ecological services from federal lands.

- **Households**: higher quality of life insofar as healthy watersheds produce more natural-resource amenities.

- **Poor households**: higher standard of living, insofar as they often bear the brunt of environmental disasters and restoration would diminish the risk of such disasters.

- **Firms**: higher profits, insofar as the households attracted by the higher quality of life expand both the supply of available workers and the pool of consumers.

- **Property owners**: reduced risk of flood damage and debris flows insofar as restored watersheds slow down the peak runoff from storms.

- **Taxpayers**: more efficient government, insofar as degraded watersheds stimulate greater costs for control of floods, erosion, wildfires, noxious weeds, etc.

- **Municipal water consumers**: lower rates, insofar as healthy watersheds deliver water with higher quality.

Next Steps

This report lays the foundation for linking ecological and economic benefits in a watershed-restoration program for the Sierra Nevada. To that end, Pacific Rivers Council, ECONorthwest, and others intend to build on this framework to complete the following objectives:

- Develop a detailed restoration program for federal lands.

- Develop a detailed restoration program for non-federal lands.

- Develop detailed economic analyses for watershed-specific restoration programs.

- Develop a strategy for implementing restoration programs.
- Develop transition plans for affected communities.

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READER'S GUIDE TO THIS REPORT

WHAT IS THIS REPORT?

This report presents initial findings from a multi-year project to develop a solid, long-run, financial foundation for watershed restoration in the Sierra Nevada. The Sierra Nevada Aquatic Conservation and Restoration Project arises from the observation that, although maintaining and restoring the ecological health of watersheds can generate substantial economic benefits, the watersheds of the Sierra Nevada have been seriously degraded in the past, further degradation occurs today, and the existing restoration programs too often do too little, too late to be effective. Degradation of these watersheds is a concern because it yields:

Ecological stress and crises. These may materialize, for example, through additions to the list of species in the Sierra Nevada that are at-risk of extinction.

Reduced economic welfare. Watersheds produce many valuable goods and services. Mounting evidence indicates that past and current patterns of resource use in many watersheds have left them incapable of producing the bundle of goods and services with the greatest value. In yesterday's economy, degrading activities, such as intensive logging, grazing, and damming of streams, made economic sense. But in today's economy, these activities are less important economically and it makes more sense to focus on allowing watersheds to provide clean water, high-value recreational opportunities, and a wide array of natural-resource amenities. An efficient restoration program, together with compatible changes in land-use and water-use patterns, would increase the economic well-being derived from the watersheds.

Economic burdens for future generations. There is widespread agreement that allowing ecological problems to develop and then trying to fix them is more expensive than preventing the problems in the first place. Hence, the longer the delay in implementing a scientifically and economically sound restoration program, the greater the burden being imposed on future generations.

This report takes some important first steps toward establishing a financial foundation for watershed restoration in the Sierra Nevada. Chapters 1 and 2, written with the scientific expertise of the Pacific Rivers Council, describe the extent of past and ongoing degradation of watersheds in the Sierra Nevada and identify the factors that are contributing most to further degradation on federal lands. The emphasis on these lands reflects the fact that far more is known about the status of federal lands and what to do to rehabilitate them. Chapter 2 also includes a detailed outline of what a scientifically sound restoration program would look like and a risk assessment of recommended passive and active restoration measures, setting the stage for defining watershed-specific restoration programs that incorporate both federal and non-federal lands.

Chapters 3-5, drafted with the economic expertise of ECONorthwest, describe how implementation of a watershed-restoration program would affect the area's economy. Because the literature on the economic issues associated with watersheds in the Sierra

Nevada is limited, much of the discussion in these chapters focuses on describing the different ways in which the status of watersheds affects the economy.[1] This discussion shows that the economy is evolving, with ecological services such as clean water becoming more important relative to commodities, and the economic well-being of the area's residents depends more on enhancing these services and less on traditional, resource-related industries, such as timber.[2] This evolution is important because, whenever watershed restoration significantly increases the ecological services it also generates economic benefits and, at least in concept, some of these benefits could be tapped to provide funding for restoration. The evolution of the economy also is important because it means that some of the potential economic costs of restoration, such as reductions in timber-industry jobs, are becoming smaller.

Chapter 6 describes the five next steps that must be taken to bring about increased, reliable funding for watershed restoration in the Sierra Nevada. These are: (1) develop a detailed restoration program for federal lands; (2) develop a restoration program for non-federal lands; (3) develop economic analyses of watershed-specific restoration programs; (4) develop a strategy for implementing restoration programs; and (5) develop transition plans for affected communities.

WHY WAS THIS REPORT PREPARED?

The watersheds of the Sierra Nevada have always played a central role in California's environment, society, and economy. They produce more than one-quarter of all the flow in the state's rivers, provide water for many of the state's farms and cities, support recreational opportunities for millions of people each year, contain rich—though often fragile—ecosystems, and offer spiritual sustenance to all who experience them. Without wise management, however, the watersheds' value will be diminished. Indeed, past management has left many watersheds functioning below their full potential. For the foreseeable future, stresses on all the watersheds—and the challenges facing landowners, water users, taxpayers, and political leaders—will increase sharply, driven by several powerful forces, including these:

- The human population located in or near the Sierra Nevada is expected to double by 2040 (Duane 1999).
- The state's economy will evolve toward industries with different water requirements than those that were the sources of past prosperity.

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[1] Sohrakoff (1999), in a review of the literature regarding the potential for improving water quality and supply, observed (p. 5): "The single most important conclusion highlighted by this report is that very few studies address the economics of watershed restoration in terms of monetary benefits or avoided costs." Even Sohrakoff's report, however, does not explain the fundamental relationship between watersheds and the economy.

[2] It is important to note that there are community-level economic differences that will influence a community's response to changes. Some Sierra Nevada communities are integrated into metropolitan labor markets and experiencing population growth, others are more dependent on traditional resource extraction industries.

- Californians' preferences for enhanced amenities linked to watershed-related natural resources should increase as disposable incomes rise.

- The public's concern for environmental protection should continue to rise.

Within this context, many have concluded it is imperative to initiate and sustain efforts to correct past damage to Sierran watersheds and to prevent further damage. To be effective, however, these efforts must be both ecologically sound and economically feasible. Accordingly, the Pacific Rivers Council initiated a multi-year project to assess the severity of the ecological problems in the watersheds of the Sierra Nevada, define a restoration program based on broad scientific principles, assess the potential economic impacts of implementing (or not) the proposed restoration program, identify ways to secure sustained funding for restoration, and develop a politically feasible implementation plan. Pacific Rivers Council contracted with ECONorthwest, an economics and financial consulting firm, to assist with the preparation of this report.

WHO PREPARED THIS REPORT?

Deanna Spooner, Jenna Borovansky, and David Bayles, with Pacific Rivers Council, prepared Chapters 1, 2, and Appendix A, and contributed to Chapter 6. Ernie Niemi and Anne Fifield, with ECONorthwest, prepared Chapters 3-6 and Appendix B.

We are grateful to the various foundations for funding assistance and to the numerous individuals who patiently provided insights and other assistance in helping us understand the ecological and economic characteristics of the Sierra Nevada. We especially acknowledge help from Nick Bollman, Bill Center, Matt Kondolf, George Miller, Andrea Lawrence, Sue Britting, and Tim Duane. Additionally, this report would not have been possible without the critical research conducted by consulting hydrologist Jonathan Rhodes of *Planeto Humido y Azul*. We alone, however, are responsible for the report's contents.

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We have prepared this report based on our specific knowledge of the watersheds and economies in the Sierra, as well as our general knowledge of the interactions between watersheds and economies. Throughout the report we rely on information derived from government agencies, private statistical services, the reports of others, interviews of individuals, or other sources we believe to be reliable. We have not verified the accuracy of information obtained from elsewhere, however, and make no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute our current opinions, which may change as more information becomes available.

HOW CAN YOU GET MORE INFORMATION?

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CHAPTER ONE: WATERSHED RESTORATION – WHAT IS IT AND WHY SHOULD WE CARE?

While some of the magnificent scenery of the Sierra Nevada region of California has been preserved and protected—towering Sequoia trees, granite escarpments in Yosemite National Park, the unique cobalt-blue Lake Tahoe—the Sierra Nevada's watersheds have not. Although Sierra watersheds are characterized by a remarkable diversity of aquatic habitats they also are characterized, unfortunately, by a long history of degradation.

This degradation has important environmental and economic implications. Watershed degradation affects the quantity and quality of water itself, the quality of life for those who live in or near the watersheds, and the values of fish and other aquatic-dependent species.

Recently, awareness of watershed degradation has grown. Rural counties, agencies, and conservationists alike are coming to realize that ecologically functioning watersheds possess an enormous but largely undocumented economic value. Urban water utilities and their customers also are beginning to recognize the value of relying on healthy watersheds to deliver water that requires less treatment. Moreover, Sierra Nevada watersheds now are being called upon to support local communities that are facing unprecedented growth but limited water supplies.

Watershed: A catchment or drainage basin of approximately 20 to 200 square miles that shapes and defines the aquatic characteristics of a landscape, including headwater tributaries, mainstream reaches, and floodplains.

Riparian Areas: Three-dimensional zones of direct interaction between aquatic and terrestrial ecosystems.

Unfortunately, existing water and land management practices do not promote effective watershed protection and restoration. Federal, state, and local agencies have yet to adopt a true watershed approach for protecting and restoring aquatic systems within existing land and water management frameworks. Most restoration projects are designed to target specific degraded sites rather than adopt a whole-watershed approach that prioritizes protective and restorative activities to achieve the greatest ecological and economic benefit over the long term. Often only the costs of restoration work are estimated while the ecological and economic benefits are underestimated or not recognized at all. Without a better understanding of the true economic consequences of watershed protection and restoration, resource managers, political leaders, and the general public will have little to no incentive to restructure management decisions along sound ecological lines.

Meeting the legal requirement and societal desire for healthy watersheds requires a thorough ecological understanding of and a principled decision to focus on underlying processes, functions, and relationships rather than on the symptoms of watershed failure or health.

The National Research Council defines restoration as the "re-establishment of the structure and function of a watershed ecosystem, including its natural diversity." In portions of the Sierra this goal may be impossible to reach (e.g., many urban areas); however, due to the fact that the majority of the region is comprised of public lands, federally guided watershed restoration could be achievable at an appropriate ecological scale if properly prioritized above other land management activities. This chapter outlines the needs and goals of watershed restoration in the Sierra Nevada, while the following chapter discusses in detail the most pervasive sources of degradation and how to begin reversing them.

WHY IS WATERSHED RESTORATION NEEDED?

The Sierra Nevada is blessed with a wealth of streams, rivers, and lakes that provide habitat for fish and other species, unparalleled recreational and scenic opportunities, and drinking water for much of the state's populace. However, a recent assessment of the greater Sierra Nevada ecosystem found that aquatic and riparian (streamside) ecosystems are the most altered and impaired systems in the range (SNEP 1996). Watershed degradation is extremely widespread in the Sierra Nevada—endangered species problems are common and large-scale *non*-degraded watersheds are rare.

It comes as no surprise, then, that the aquatic species of the Sierra are imperiled. The watersheds of the Sierra Nevada support forty native fishes and thirty native amphibian taxa (Moyle et al. 1996; Jennings 1996), many of which have experienced serious population declines. Among these, six fishes and one amphibian are listed under the Endangered Species Act (ESA): the winter- and spring-run chinook salmon, Central Valley Steelhead, Little Kern golden trout, Lahontan cutthroat trout, Paiute cutthroat trout, and the California red-legged frog. Additionally, two amphibians are candidates for listing and two more have been petitioned for listing: the California tiger salamander, spotted frog, mountain yellow-legged frog, and the Yosemite toad, respectively. Many more species have been recognized as in need of special protection because of their poor status (Jennings and Hayes 1994; Moyle et al. 1996b). Factors influencing the decline of native fishes and amphibians of the Sierra Nevada include the physical, biological, and chemical modification of their habitats. These detrimental influences reflect a national trend of assault on aquatic resources (Williams et al. 1989; Nehlsen et al. 1991; Williams et al. 1993; Warren et al. 1994; Taylor et al. 1996) and represent an array of activities, including:

> **Protecting Refugia:** It is essential to protect the remaining healthier watersheds that serve as refugia (called Critical Aquatic Refuges in the US Forest Service's Sierra Nevada Framework) from all damaging land management activities. Preventing further degradation of these areas is the only hope for maintaining the existing levels of species and ecosystem health.

- modification or destruction of habitat through poor land management practices that focus on commodity production (e.g., timber, livestock, and mining operations and associated road construction and maintenance);

- alteration of natural flow regimes and impairment of migratory corridors (e.g., via dams, diversions, groundwater withdrawal, and degradation of riparian areas);
- increased urbanization (e.g., producing direct effects from encroachment as well as indirect effects resulting from changes in management of the urban-wildlands interface);
- introduction of exotic species (e.g., resulting in competition, predation, and hybridization with native taxa); and
- changes in water chemistry (e.g., as a result of continuing acid mine drainage and agricultural runoff as well as increased air pollution).

In addition to their effects on fishes and amphibians, these detrimental changes in aquatic ecosystem function and loss of biological integrity also have triggered declines in many plants, invertebrates, reptiles, birds, and mammals that are dependent upon a properly functioning aquatic and riparian community and high quality habitats.

THE ELEMENTS OF WATERSHED RESTORATION

Watershed restoration is the implementation of a landscape level strategy that attempts to recover the ecological integrity of watersheds and the species that depend on them, always prioritizing those places where structure, function, and natural diversity can most effectively be recovered at the least cost. Watershed restoration is aimed at aiding the natural recovery of the system itself, not at quick fixes for individual degraded sites. Therefore, the first step before restoration should be identification and protection of areas where the natural system itself is still functioning well: the best remaining habitat for aquatic species. These "best" highly functioning areas serve as refugia, or strongholds for aquatic diversity. Ecologically effective watershed restoration must begin with the full *protection* of refugia, critical aquatic corridors, and riparian areas throughout the landscape. Without effective protections for areas where the natural system is still functioning well, any restoration strategy will fail. The classic formula for restoration – that of trying to recover a semblance of health at the worst sites – is backwards and will yield the least recovery of ecosystem function at the most cost.

Steps in Implementing Watershed Restoration

Watershed restoration is a four-step process: analysis, protection, passive restoration, and/or active restoration. The steps are sequential: analysis should precede protection, and both analysis and protection should precede restoration of either sort, passive or active.

I. LANDSCAPE AND WATERSHED LEVEL ANALYSIS

Watershed protection and restoration should be based on analysis first at the *landscape* level, to target the watersheds most predisposed to recovery, and second at the watershed level to identify the protection and restoration priorities within each target watershed.

Within each target watershed, the analysis should at a minimum:

1. Identify the areas in need of protection, including: riparian areas, unstable slopes, refugia, and other sensitive areas.

2. Characterize the natural physical processes (e.g., flow regime).

3. Identify the forces and practices that cause watershed degradation.

4. Assess the reversibility of those forces and practices.

5. Define and prioritize the suite of restoration needs, first the passive restoration needs (e.g., altering land management practices and dam operations) and then the active ones (e.g., retiring roads, removing dams, building fencing).

Only after analysis and protection of the sensitive areas should watershed restoration itself be implemented—first passively, and then (if necessary), actively.

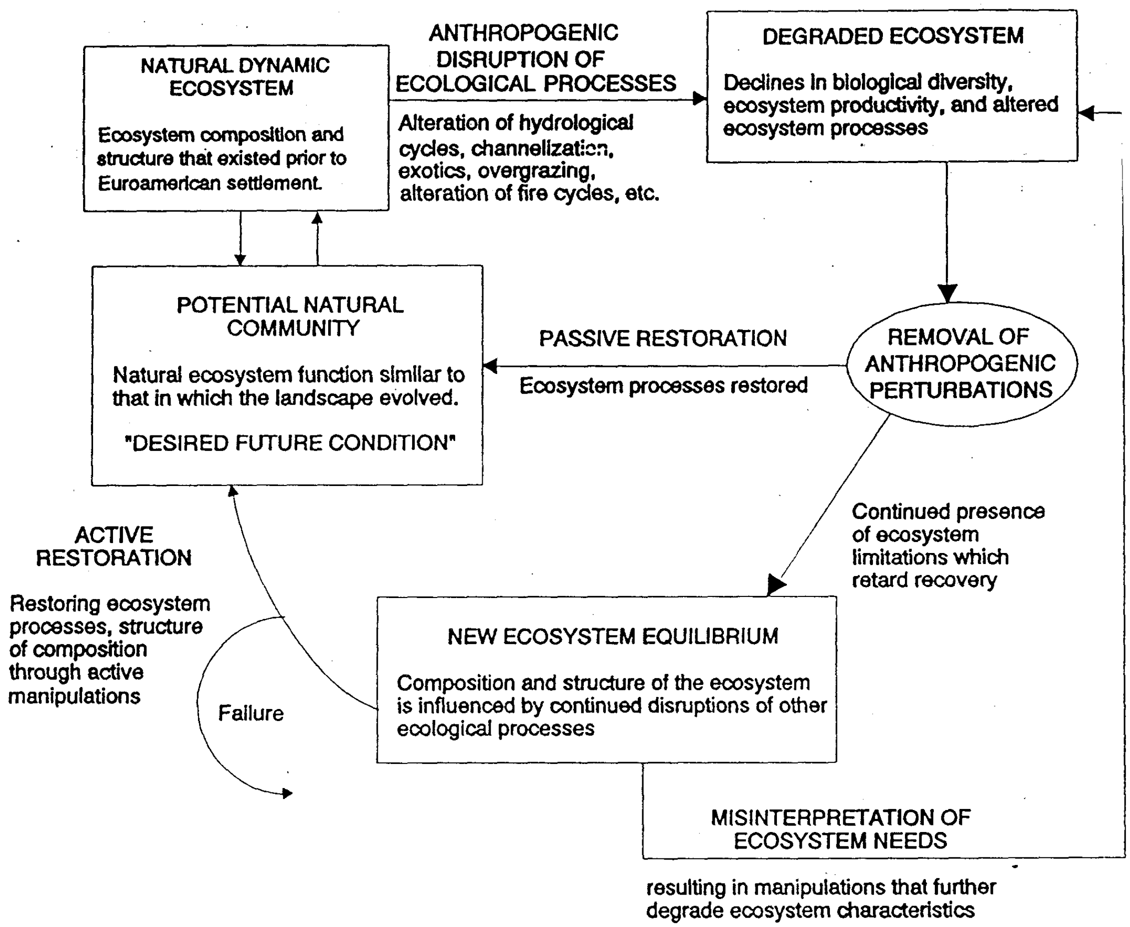
II. PASSIVE RESTORATION (REDUCING DEGRADATION)

The first step in ecological restoration is to cease activities that are causing watershed degradation. In some watersheds, no additional "restoration" steps will be necessary as natural processes themselves re-establish the structure and functions of the watershed leading to both physical and biological recovery. In all watersheds, active restoration should not proceed until the needed passive changes have been identified and the system has been allowed time to recover (Kaufman et al, 1997).

III. ACTIVE RESTORATION (REVERSING EXISTING CHRONIC STRESSES)

In many watersheds, active management may be necessary to reverse chronic stresses, re-establish ecosystem functions and processes, or even to reintroduce beneficial native species (e.g., beaver). Active restoration only should be undertaken once protection of refugia has been initiated and passive restoration measures have been implemented.

Figure 1.1: Conceptual Pathways of Ecological Restoration



Source: Pacific Rivers Council, 1996, p. 168

CHAPTER TWO: ECOLOGICAL STATUS AND RESTORATION NEEDS IN THE SIERRA NEVADA

This chapter:

- provides an overview of the current impacts of land use practices on watersheds and aquatic resources under federal management,
- summarizes the current status of activities and conditions that are causing the damage and/or retarding restoration, and
- identifies high priority restoration measures needed to reverse current ecological damage in the Sierra Nevada.

This chapter ***does not*** address watershed function of urbanized or privately held lands. The restoration of urbanized watersheds requires a radically different approach than for non-urbanized areas or wildlands, and data needed to analyze urbanized watersheds are largely unavailable. Appendix A offers further details regarding impacts from the four management activities highlighted below on various aquatic ecosystem components (soils, morphology, vegetation, flow regime, water quality, and biota) and a risk analysis of recommended passive and active restoration measures.

WATERSHED DEGRADATION: EFFECTS, CAUSES, AND RECOMMENDATIONS

Much of the public land in the Sierra Nevada has been degraded by a variety of activities over the last 150 years. Cumulatively, this degradation has severely damaged a broad spectrum of aquatic resources. Sedimentation and summer temperatures are elevated in streams over much of the region. These water quality impacts, together with stream alterations, have contributed to the diminution in the number and diversity of native aquatic and riparian fauna, including stream invertebrates, fish, and amphibians. Native anadromous fish are extirpated from most of their natal streams and still are declining radically in the remaining occupied habitat. Native amphibian populations also continue to decline, primarily due to habitat loss and degradation caused by land and water uses. These adverse effects and trends have been caused, maintained, and exacerbated by land and water uses in both the past and present. Hydraulic dredge mining in the nineteenth century radically altered riparian areas, soils, and stream conditions. The effects of soil loss and elevated sedimentation caused by hydraulic mining dredging exist to this day in affected streams and watersheds despite cessation of the practice for more than a century.

The below discussion details just some of the numerous impacts that Sierran watersheds are subjected to. They may appear, at first blush, to be irreversible. However, as we demonstrate further on, many impacts can be ameliorated or even reversed *simply by halting the activities that are the sources of degradation*.

Effects of Watershed Degradation

- *Elevated Sedimentation*. Elevated sedimentation has caused and continues to cause accelerated loss of reservoir storage, thereby reducing the ability of dams and reservoirs to generate electricity, provide limited flood control, or provide water supplies for agriculture, industry and domestic consumption. Accelerated sedimentation also can reduce salmonid spawning and rearing habitat, smother fish redds, lead to direct mortality of small fishes, and cause the widening and shallowing of streams to the detriment of native aquatic fauna.

- *Degraded Soils*. Together with compaction, accelerated soil loss has diminished the productivity of Sierra soils over large areas. These same soil impacts have increased peak flows and may have reduced summer baseflows. The loss of soil productivity has diminished the potential for vegetative recovery, which is a key component of riparian habitat. This loss of productivity and consequent impacts are likely to persist for decades to centuries, even with complete avoidance of any additional impacts.

- *Degraded Riparian Areas*. Riparian habitats are the most altered and degraded habitat type in the Sierra Nevada. This has contributed to water quality deterioration and continuing declines in some bird populations, such as willow flycatchers, and many amphibian and fish populations. Noxious weeds are spreading throughout much of the Sierra and are a significant problem in many riparian areas.

- *Altered Streamflows.* Land use practices, dams, and diversions have significantly altered watershed function in the Sierra. Dams in particular contributed to the demise of many aquatic resources by blocking fish passage, altering channel and water quality conditions, severely disrupting flow regimes, and inundating large areas of riverine and riparian habitats.

Principal Causes of Watershed Degradation in the Sierra Nevada

The four most widespread activities in the Sierra that continue to contribute to declining watershed health, the variety and extent of their impacts, and priority restoration measures are:

- *Grazing.* Livestock grazing historically caused severe, widespread, long-lasting damage to soils, vegetation, riparian areas, streams, and embedded biota in the Sierra Nevada. These effects continue to persist. Although grazing pressure has been reduced over the past couple of decades, current grazing continues to stymie the natural recovery of riparian and aquatic resources throughout affected areas in the Sierra Nevada. In some areas, grazing is continuing to exacerbate currently degraded conditions. Grazing currently affects more acres of public land in the Sierra Nevada than any other land use. (*See* Menke et al., 1996.)

- *Roads.* A vast number of roads have been constructed in the Sierra Nevada, often as part of logging operations. The road network in the Sierra Nevada is widespread and an extremely significant cause of damage to water quality, riparian areas, water quantity and timing, aquatic and riparian flora and fauna, watershed functions, and streams structure.

- *Logging.* Logging also has contributed to degradation of water quality, riparian areas, soils, and aquatic resources. Many areas of the Sierra Nevada were heavily logged at the turn of the last century, with significant and persistent adverse effects on soils, vegetation, and aquatic resources. Accelerated logging on federal lands in the 1970s through the early 1990s significantly exacerbated these impacts.

- *Dams and Diversions.* Thousands of dams and diversions intercept and bisect the waterways of the Sierra Nevada, altering flow regimes, blocking fish passage, and accumulating sediment. According to a regional scientific assessment, dams are the foremost cause of riparian degradation in the Sierra foothills.

These causes of aquatic resource degradation and resultant effects are not peculiar to the Sierra Nevada. They are common throughout the West, as many recent credible scientific assessments conducted at many scales and in many locales repeatedly have concluded (e.g., Henjum, 1994; Rhodes et al., 1994; USFS 1997a, b, c; CWWR, 1996; USFS, 2000a). Streams have been homogenized by common treatments (e.g., dams, grazing, logging, roads, agriculture, urbanization) causing common effects: elevated sedimentation, simplified stream structure, elevated peak flows, increased water temperature extremes, impoverished riparian areas with non-native vegetation, and vastly reduced numbers and diversity of aquatic and riparian flora and fauna.

Impacts differ in degree, geographically, but not in type or result. One can observe the homogenization of streams simply by driving across the country from, say, eastern Montana to the Sierra Nevada. Streams that drained diverse settings and hence, historically, were quite different from one another, are now strikingly similar: raw banks, little large wood, few pools, widened, incised, limited and often non-native riparian cover, few native fish, and heavy with silt and sediment during high flows.

We must note that this report does not address fire as a watershed threat because, contrary to popular belief, fire is not a major source of watershed degradation, particularly as compared with grazing, logging, roadbuilding, and dams and diversions. Although it appears that fuel loads in the Sierra may have increased due to the effects of logging and fire suppression, it does not appear that fire extent, frequency, or intensity has increased (CWWR, 1996). Forest fuel load silvicultural treatments—which are forms of logging—have significant and adverse cumulative effects on watersheds, including soil compaction, loss of soil productivity, increased soil loss, and elevated sediment delivery (which leads to increased stream sedimentation and turbidity). These impacts are unavoidable regardless of technique or level of analysis employed. Such forest treatments also are likely to contribute to elevated peakflows and exacerbation of flooding during major events, due to increased snowmelt in opened stands and increased levels of runoff caused by compaction and soil loss (Kattelmann, 1996). Creation of defensible fuel profile zones likely will increase the spread of noxious weeds (USFS, 1999)[1], which are already a serious problem in much of the Sierra

[1] Defensible fuel profile zones are areas up to ¼ mile wide and of varying length where most ground vegetation and small diameter trees are removed in an effort to create a type of fuel break to prevent the spread of fires.

(USFS, 2000a). Notably, these negative impacts are persistent and not rapidly reversible even with expensive remediation. As Franklin et al. (2000) concluded, silvicultural fuel/forest structure often trade one sort of problem (fuel loads) for another set of problems (e.g., long term soil compaction, erosion, etc.). Notably, these negative impacts are persistent and impossible to reverse rapidly even with expensive remediation.

Undeniably, fire has played an important role in the development of Sierra aquatic-riparian systems (USFS 2000a). Available evidence does not support the contention that fire impacts on watershed and aquatic resources exceed those of silvicultural treatments and associated road-related activities. Adverse effects from fire generally are limited in extent and short-lived (1-5 years), while compaction caused by mechanical treatments typically persist for more than 30 years (pers. comm. Jonathan Rhodes). Further, adverse soil impacts and elevated runoff in burned areas typically are transient, whereas elevated erosion and sedimentation from harvested areas with roads persists for decades, even after roads no longer exist (Geppert et al., 1985; MacDonald and Ritland, 1989; Potyondy et al., 1991). Logged and roaded areas typically have greater and persistent adverse cumulative effects on soils, sediment delivery, and runoff than even intensely burned areas, as indicated by model coefficients for estimating cumulative watershed effects in the Sierra Nevada (Menning et al., 1997) and other broadly comparable areas (Potyondy et al., 1991).

In sum, silvicultural treatments to reduce fire effects are not likely to produce any palpable benefits for aquatic systems and are highly likely to cause additional damage to watersheds and embedded aquatic resources. Fire/fuels treatment is not an ecologically sound or appropriate watershed restoration approach. In addition, large-scale silvicultural experiments are extremely costly, thereby siphoning money and effort away from very pressing restoration needs such as reducing grazing pressure and aggressively reducing road impacts. Silvicultural efforts to reduce fuel loads must be rejected as a priority measure for aquatic restoration and as aquatic restoration measures in general.

There may be other compelling reasons for such attempts to reduce fire risk (e.g., presence of dwellings), but, if so, these attempts should be confined to those areas (e.g., urban-wildland interface) and not widely applied across the landscape at great monetary and environmental expense.

Approaches To Watershed Restoration

While existing problems and deteriorating trends cannot be arrested and alleviated without watershed restoration, in many cases merely suspending activities that are causing damage or preventing natural ecosystem recovery is the only restoration step required. The suspension of damaging activities has been termed “passive restoration” (Kauffman et al., 1993; Rhodes et al., 1994).

In other cases, the restoration of watersheds and aquatic resources requires intervention to restore watershed condition and function (e.g., road obliteration). This approach has been termed “active restoration.” To use an analogy, smoking cessation for someone with heart disease is an example of passive restoration. Open-heart surgery would be an example of active restoration. Just as the benefits of open-heart surgery are likely to be limited without smoking cessation, active restoration typically has limited or few benefits for aquatic resources without passive restoration.

Effective watershed restoration requires that the causes of degradation be fully addressed. Treating the symptoms of degradation seldom has any lasting benefits and is usually an inefficient use of resources and funds and also can exacerbate rather than ameliorate degraded conditions (Kauffman et al., 1993; Kauffman et al., 1997). As many researchers repeatedly have stressed, the avoidance of damage is far more ecologically effective, and biologically and financially efficient, than attempting to reverse or reduce impacts after the fact (e.g., Reeves et al., 1991; Henjum et al., 1994; Rhodes et al., 1994; ISG, 1996; Espinosa et al., 1997; CWWR, 1996).

Priority Restoration Measures

This report focuses on four general categories of land and water uses that are of high priority for targeted reform in order to facilitate watershed restoration: grazing, logging, roads, and dams and diversions. These categories were selected because they meet the following four criteria:

- They are a significant cause of degradation or are preventing or retarding recovery over significant areas. On-going and/or planned future levels of these activities or conditions are likely to prevent recovery or increase existing degradation.

- Available data, case histories, and other scientific information indicate that treatment of these conditions or activities via either passive or active restoration will result in tangible benefits within 1-10 years.

- Treatment generally is cost-effective.

- Passive and/or active restoration efforts do not convey a high risk of additional damage that likely will outweigh potential benefits.

Other land use changes and restoration measures were not considered in detail because adequate treatment of the priority activities and conditions likely will fully expend restoration budgets over the mid-term (10 years). Priority treatment of the identified land uses does not negate the need to cease all damaging activities in critical aquatic refugia and riparian areas in order to achieve maximum benefit from the suggested restoration efforts.

LIVESTOCK GRAZING

Extent and Magnitude of Activity

According to United States Forest Service (USFS, p. S-42, 2001) there are 463 grazing allotments[2] on national forest lands in the Sierra Nevada. Of those, 411 are active and grazed. The USFS Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement (SNFEIS) (id.), indicates that active grazing allotments currently cover approximately 7,165,000 acres or about 62% of national forest lands in the Sierra Nevada. However, since most allotment boundaries are not typically fenced, it is likely that many more acres are directly affected by grazing via straying of livestock outside the allotment boundaries. Therefore, the actual acreage affected by active allotments may be more than 10% higher than the official estimate of the area of the allotments.

The area of active allotments probably underestimates the area affected by grazing because it does not include the allotments that are currently inactive. It is possible that some currently inactive allotments may be re-activated in the near future and/or only recently became inactive. Depending on the time grazing ceased, it is likely that these allotments have persistent watershed and stream effects. Using an average allotment area of 17,433 acres,[3] the area of the 52 inactive allotments is estimated to be about 906,531 acres, bringing the total area of all allotments to 8,071,616 acres or about 70% of the total land base, assuming there have been no grazing effects outside of the allotment boundaries. Using the conservative assumption that actual grazing has affected an additional 10% of the area, it is likely that about 77% of national forest lands in the Sierra Nevada have been, or are, affected by recent livestock grazing. Under any of these area scenarios, grazing is the land use that directly affects more acres of Forest Service land than any other land use in the Sierra Nevada.

The Forest Service estimates that about 376,800 of the AUMs[4] on national forest lands are cattle, with the remaining 48,000 comprised of sheep (USFS, p. 5.1-31, 2001). The SNFEIS (2001) forecasts that AUM levels will decline in the future under the soon to be implemented management plan. However, revision schedules for allotment management plans (AMPs) are not frequently met. For instance, the 1990 Forest Plans for Washington and Oregon promised that all AMPs on each forest would be revised within 10 years to meet newly adopted standards and guidelines for forage use and stream condition (e.g., Malheur National Forest, 1990). Although there are approximately 250 allotments on these forests within the Columbia River basin, less than 10 of these AMPs have been fully and officially revised within the 10-year timeline. At this rate, more than 250 years would be required to revise all of the allotments. This indicates that Forest Service projections of reduced grazing pressure based

[2] An allotment is a privately held permit to graze cattle or other livestock on public lands for a designated time period annually. Permits are generally granted for 10 or more years.

[3] The average allotment area was estimated using the official estimate of the total area of active allotments, divided by the number of active allotments.

[4] AUM = Animal Unit Months, which is equal to the amount of forage that will sustain one cow and calf for one month.

on incorporation of standards and guidelines overestimate reductions in grazing pressure because the pace of scheduled change typically takes longer than projected.

Historic and Ongoing Effects of Grazing on Aquatic Resources

There is a clear consensus in available scientific assessments of the ecological condition of the Sierra Nevada that historic overgrazing has had widespread, multiple, and acutely negative effects on almost every aspect of watershed condition and function including: vegetation, soils, runoff regimes, riparian areas, meadows, wetlands, erosion and sedimentation dynamics, noxious weeds, channel form, bank stability, stream substrate, water temperature, water quality, aquatic habitats and species, and water tables (CWWR, 1996; USFS, 1999; USFS, 2000a). The Center for Water and Wildland Resources Report (CWWR Report) noted that in some cases, the damage caused by historic grazing might be irreversible. The loss of thousands of years worth of topsoil formation due to vastly elevated erosion from livestock grazing is an example of an impact that cannot be mitigated within the time frame of a typical restoration project.

The Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement ("SNFEIS") (p. 33.4-32, 2001) estimates that about 79% of all meadow acres are found within active allotments. The agency rated 12% of grazed meadows in "poor" condition, about 42% in "fair" condition, and about 46% in "good" condition. However, these assessments of meadow condition are based on forage conditions (i.e., amount of food available for livestock) rather than ecological conditions and status (USFS, p. 5.3-403, 2001). Ecological conditions of meadows generally tend to be much worse than forage conditions. In fact, the Sierra Nevada Ecosystem Project Report (1996) evaluated meadow conditions based on a series of ecological indicators and found that "[c]urrent livestock grazing practices continue to exert reduced but *significant* impacts on the biodiversity and ecological processes of many middle- to high-elevation rangelands even though properly managed grazing…can be compatible with sustainable ecological functions" (pg. 114, emphasis added). One of the "red flag" indicators was the presence of "more than 7%-10% bare soil in wet meadows, indicating severe abuse" beyond natural erosive factors such as burrowing rodents (SNEP, pg. 116).

Although grazing pressure on national forest lands has been somewhat reduced over the last two decades, available information indicates that grazing continues to damage aquatic resources annually in many areas and is certainly retarding recovery in most areas. Livestock grazing continues to affect erosion and sedimentation, runoff, vegetation, riparian areas and channels, and aquatic habitats and associated species.

Recommended Approach for Grazing

Due to the myriad benefits of grazing cessation and the lack of potential ecological risks, the recommendations of Anderson et al. (1993), Henjum et al. (1994), and Rhodes et al. (1994) should be followed. Grazing should be suspended in biologically sensitive and degraded areas until affected terrestrial, riparian, and aquatic conditions are fully assessed. Exclosures are the best tool for accomplishing this goal. If building exclosures is not feasible, then cattle and other livestock should be actively herded to keep them out of these important areas. If active herding also is impractical, then complete cessation of grazing within the affected area may be required. Grazing should be re-introduced only where there is a high degree of certainty that it will not stunt recovery and there is annual monitoring of affected resources, including vegetation re-growth and bank stability. Monitoring should occur both within grazed areas and in applicable ungrazed exclosures in riparian areas. If such exclosures do not exist, they should be constructed (Anderson et al., 1993). Grazing only should be allowed where annual monitoring indicates that recovery of riparian and aquatic attributes in grazed areas is as rapid as in ungrazed exclosures. If grazing outside of exclosures indicates that recovery is being retarded it should be suspended.

First and foremost, grazing should be suspended in degraded areas, key habitats, and areas where grazing is clearly incompatible with habitat recovery. Key habitats would include habitats for threatened, endangered or sensitive species. Degraded areas would include riparian areas with bank stability problems, incised channels, elevated water temperatures, minimal shading, or high levels of sedimentation.

Table 2.1:Grazing: Scale and Effects on Sierra Nevada Watersheds

Current Scale of Activity or Condition	**Negative Physical Effects on Watershed Condition or Function**		**Effects of Grazing on Fauna**		**Effects of Grazing on Beneficial Uses of Watersheds**	
	Increases:	***Decreases:***	***Increases:***	***Decreases:***	***Increases:***	***Decreases:***
• 411 active allotments covering 7,165,085 to 7,881,593 acres • 463 total allotments covering 8,071,616 to 8,878,778 acres • Animal Unit Months: 412,734 to 464,326	• soil compaction • erosion • sediment delivery, sedimentation • seasonal water temperature extremes • stream incisement • flooding • noxious weeds, cheatgrass • fecal coliform in streams, lakes, and reservoirs • nutrient pollution in streams, lakes, and reservoirs	• soil productivity • bank stability, undercut banks, pool volume • water table elevation, baseflows • stream shading, groundcover, hydric species	• accelerated eutrophication in lakes and reservoirs	• habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity • willow flycatcher habitat • willow flycatcher populations	• storage loss in reservoirs	• useful reservoir life, water supplies in reservoirs

Table 2.2: Grazing: Ecological Restoration Needs in Sierra Nevada Watersheds

<table>
<tr><th colspan="4">Passive Restoration Needs and Measures (Active restoration needs and measures typically are ineffective to address grazing)</th></tr>
<tr><td colspan="4">Very High Need For:</td></tr>
<tr><td colspan="4">• Suspension of grazing in damaged but resilient areas.
• Elimination of grazing in areas with at-risk aquatic species and critical aquatic areas.</td></tr>
<tr><td colspan="4">Ecological Risks:</td></tr>
<tr><td colspan="4">• There are virtually no ecological risks in limiting grazing.</td></tr>
<tr><th colspan="2">Ecological Benefits of Passive Restoration</th><th colspan="2">Economic and Logistical Benefits of Passive Restoration</th></tr>
<tr><th>Increases:</th><th>Decreases:</th><th>Increases:</th><th>Decreases:</th></tr>
<tr><td>• soil productivity
• bank stability, undercut banks
• pool volume
• water table elevation, baseflows
• stream shading, groundcover, hydric species
• useful reservoir life, water supplies in reservoirs
• habitat quality and quantity for salmonids and amphibians
• salmonid and amphibian populations and population connectivity
• willow flycatcher habitat</td><td>• soil compaction
• erosion, sediment delivery, sedimentation
• seasonal water temperature extremes
• surface runoff
• rate of spread of noxious weeds, cheatgrass
• stream incisement
• fecal coliform in streams, lakes, and reservoirs
• nutrient pollution in streams, lakes, and reservoirs</td><td>• effectiveness of noxious weed control
• useful reservoir life, water supplies in reservoirs</td><td>• range administration, monitoring, fencing, and mitigation costs
• storage loss in reservoirs</td></tr>
</table>

ROADS

Extent and Magnitude of Activity

The Forest Service estimates that there are approximately 25,000 miles of inventoried forest transportation roads on Forest Service lands in the Sierra Nevada (USFS, p.5.5-3, 2001.) The agency estimates that there are another 5,124 miles of uninventoried and unclassified roads[5] on Forest Service lands (id). Surveys in other areas (USFS, 1995; CNF, 1998; Rhodes et al., *in process*) indicate that uninventoried roads can comprise more than 25-50% of the inventoried road network. Therefore, it is likely that uninventoried roads actually total more than 6,000 miles. Notably, on a per unit area, uninventoried and unclassified roads can cause the greatest magnitude of watershed damage per unit area of road. This is because such roads typically have no maintenance of any type, increasing the severity of effects on erosion, drainage, sediment delivery, and sedimentation (Kattelmann, 1996).

Information in the both the SNFEIS and the Sierra Nevada Draft Environmental Impact Statement (SNDEIS) can be used to estimate road miles on private lands in the Sierra Nevada, even though neither the SNDEIS nor the SNFEIS discloses actual estimates of these road miles. Using the average road crossings per mile of road for Forest Service lands, the road crossing data in the SNDEIS (USFS, p. 3-7, 2000a) results in an estimate of 9,083 to 10,460 miles of road on private lands.

The maintenance level[6] of a road can provide some general indication of the likely magnitude and type of aquatic damage caused per unit of road area. The estimated miles of inventoried roads by level of road maintenance (USFS, p.5.5-2, 2001) are displayed in Table 2.3. The SNFEIS (id.) indicates that it is reasonable to assume that most of the roads in the category of maintenance level 2 (i.e., non-paved and minimally maintained) are associated with degradation. Notably, there are far more miles of road in this category than any other (Table 2.3).

While roads with lower maintenance levels often cause more types of and greater damage than roads in higher maintenance level categories, the reverse also is often true. Roads in the higher maintenance level categories often are constructed in fairly close proximity to streams and have greater levels of traffic than roads in lower maintenance categories. Erosion and sediment delivery from non-paved roads increase with increasing traffic, even with increased maintenance (Kattelmann, 1996). While paving reduces erosion from drivable surfaces, it vastly elevates runoff, contributing to flooding and accelerated erosion of fills and road ditches. Accelerated runoff from paved surfaces also contributes to increased mass wasting

[5] Uninventoried and unclassified roads are generally user-created roads that have not been designed or maintained to any standard. These are not the same as local county roads funded by timber sales receipts.

[6] According to USFS (2001) the criteria for the maintenance level categories are as follows: 1= closed for at least a year's duration, at least intermittently; 2 = high clearance roads; 3 = passable in passenger car; 4 = moderate comfort road; 5 = usually paved and able to accommodate two lanes of traffic.

(e.g., landslides) and risk of culvert failure during floods. As will be discussed in the following section, many road impacts do not vary significantly with maintenance levels.

Table 2.3: Miles of Road by Category of Road Maintenance Level on Forest Service Lands in the Sierra Nevada

	Maintenance Level					
	1	**2**	**3**	**4**	**5**	**Total Levels**
Miles of Road	3,375	14,457	4,506	1,559	1,077	24,974

Source: SNFEIS (p.5.5-2, 2001)

1= closed for at least a year's duration, at least intermittently; 2 = high clearance roads; 3 = passable in passenger car; 4 = moderate comfort road; 5 = usually paved and able to accommodate two lanes of traffic.

The miles of inventoried roads on USFS lands also vary among "functional" classes of road (Table 2.4). The vast majority of inventoried roads (77.2%) on USFS lands are classified as local roads. Comparison of Tables 2.3 and 2.4 indicates that "local" roads roughly are equivalent to road maintenance levels 1 and 2, collector roads are usually at maintenance level 3, and arterial roads are largely at maintenance level 4 and 5. Arterial roads tend to be proximate to streams, are wider, and carry more traffic, increasing the damage per unit of length of road, especially with respect to erosion and runoff impacts. Local roads tend to have higher impacts per area due to lower maintenance levels (with respect to surface erosion).

As with maintenance levels, the functional class of a road provides a reliable indicator of the Forest Service's willingness to relocate or decommission roads. The SNFEIS (p. 5.5-9, 2001) states that all collector and arterial roads will remain in their current location for the foreseeable future under the chosen management strategy for the Sierra Nevada forests. Apparently, this is regardless of how much damage to aquatic resources is caused by individual segments of these road system or the roads as whole (id.).

Table 2.4: Miles of Road in Forest Service "Functional" Road Classes within the Sierra Nevada

	Functional Road Class			
	Local	**Collector**	**Arterial**	**Total—All Classes**
Miles of Road	19,287	3,492	2,195	24,974

Arterial roads are defined as main roads traversing large areas, usually higher in standard, and maintained for higher speeds. Local roads access small areas, and often are lower standard. Collector roads often connect arterials to local roads and are midway in standard (USFS, 2001).

Source: USFS (p. 5.5-3, 2001)

The range of degradation and magnitude of damage to aquatic resources from roads generally increases with the corresponding proximity to streams. Stream crossings, in particular, damage aquatic resources in several fundamental ways (e.g., disrupting groundwater flow, concentrating runoff, interfering with stream morphology, etc.) (Rhodes et al., 1994; Jones et al., 2000). The SNDEIS (p.3-117, 2000a) estimates that there are 95,983 road crossings on Forest Service lands in the Sierra Nevada. Assuming that the estimate of road crossings is for inventoried forest development roads,[7] there are about 3.8 stream crossings per mile of road or about one crossing every 0.26 miles, on average. If uninventoried road miles were included in the estimate of road crossings in the SNDEIS (2000a), there are about 3.3 stream crossings per mile of road on average. Either estimate indicates that the bulk of the road system is in relatively close proximity to a stream. If inventoried roads were not included in the estimate of stream crossings, there may be another 15,360 to 23,040 stream crossings, using the average number of crossings per mile of road. This would bring the estimate of road crossings on Forest Service lands to somewhere between 111,343 and 119,023 crossings. Data from the SNDEIS (p. 3-7, 2000a) indicate that there are another 34,517 road crossings on private lands in the Sierra Nevada. Further, the SNFEIS (p. 3.4-19, 2001) estimates that some very large watersheds have even higher road densities (e.g., the mid North Fork American River contains 4.73 crossings per square mile).

Historic and Ongoing Effects of Roads on Aquatic Resources

It is widely acknowledged that roads are one of the greatest and most persistent causes of aquatic resource degradation in managed watersheds, especially when they are within riparian zones (Geppert et al., 1985; Meehan, 1991; USFS et al., 1993; Rhodes et al., 1994; CWWR, 1996; USFS, 1999; Jones et al., 2000; USFS, 2000a; Trobulak and Frissell, 2000). Roads have a wide variety of negative effects on a range of watershed elements and processes essential to aquatic and riparian habitats and the biota that depend on them. Roads in riparian areas, or otherwise in close proximity to streams, cause even more types of havoc and to a greater intensity than roads in uplands. Unfortunately, the adverse effects of roads are generally the most persistent of widely implemented land-use impacts in forests.

Although Best Management Practices (BMPs) and some types of road maintenance and improvement provide nominal reduction in some types of damage caused by roads, they do not come close to reducing road impacts to ecologically insignificant levels. Further, several types of environmental damage caused by roads cannot be reduced by BMPs. For instance, the loss of large woody debris (LWD) recruitment from roads in riparian areas and the interception of subsurface flows at road cuts cannot be ameliorated by BMPs. Zeimer and Lisle (1993) and the Independent Science Group (ISG) (1996) indicate that there are no reliable data showing that BMPs are cumulatively effective in protecting aquatic resources. Espinosa et al. (1997) provided evidence from case histories in granitic watersheds in Idaho that BMPs thoroughly failed to cumulatively protect salmonid habitats and streams from severe damage from roads and logging. In analyses of case histories of stereotypical resource degradation by stereotypical land management (logging, grazing, mining, roads), several

[7] The USFS (2001) never states whether the total includes or excludes stream crossings by uninventoried and unclassified roads.

researchers have concluded that BMPs actually increase watershed and stream damage because they encourage heavy levels of resource extraction under the false premise that resources can be protected by BMPs (Stanford and Ward, 1993; Rhodes et al., 1994; ISG 1996; Espinosa et al., 1997). Stanford and Ward (1993) termed this phenomenon the “illusion of technique.”

BMPs also have limited effectiveness because their implementation is often inconsistently monitored. Commonly, BMPs that are called for in environmental assessments for road construction, reconstruction, and use either are not implemented or are implemented incorrectly. Further, the USFS lacks the budget to nominally maintain the existing road network (USFS, 2000b), much less maintain all roads at the best possible standard for limiting aquatic resource damage. In the project area for the Quincy Library Group FEIS (Quincy FEIS, 1999)[8], only about 57% of the road network was partially maintained in 1998 (USFS, 1999). Most road crossings in the project area only were designed to pass a 50-year flood event (USFS, 1999), while elsewhere federal land management agencies have recommended reconstructing all crossings to pass the 100-year flood event (USFS et al., 1993). Even if it is conservatively assumed that only 50% of the 111,343 - 119,023 road crossings on forestlands in the Sierra Nevada are inadequate to pass the 100-year flood, more than 55,000 road crossings would have to be reconstructed to meet the recommendations of USFS et al. (1993). It is unlikely that the Forest Service has the budget to reconstruct this many road crossings over the next decade while providing nominal road maintenance on existing roads, especially since it has failed to maintain more than 50% of the road network in a substantial area covering three forests in 1998 (USFS, 1999).

Current and proposed riparian protection widths and measures in the Sierra Nevada national forests (USFS, 1999; USFS, 2001) are inadequate to protect streams from the on-going impacts of existing roads and the increased impacts from road construction, reconstruction, use, and maintenance (Rhodes et al., 1994). These so-called protections[9] are especially inadequate for ephemeral and intermittent streams that comprise the vast majority of the channel network. Due to their relative ubiquity, position, sensitivity, and influence on downstream conditions, the failure to protect non-perennial streams ensures that roads also will damage downhill perennial streams and related activities.

A much different approach is needed to reverse this pervasive trend, mainly, not building new roads and reducing the size of the current road system.

The cessation of road construction has added economic and logistical benefits. It prevents adding to the formidable backlog of currently identified road maintenance and obliteration needs. It also saves considerable money. Road construction and reconstruction are expensive on their own. However, they usually require considerable environmental analyses and public involvement efforts that also are expensive. Forgoing road construction and reconstruction could save vast sums of public money. The money and effort saved by the cessation of road

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[8] The Quincy FEIS covers over 1.5 million acres spanning all or part of 3 national forests in the northern Sierra.

[9] The riparian widths and measures specifically and clearly allow significant damage to streams and, therefore, cannot be accurately termed stream "protection." Webster’s Dictionary defines protection as "to keep from harm, attack, or injury."

construction could be diverted into needed road obliteration or maintenance or it could be returned to the treasury or taxpayers.

Recommended Approach for Roads

The adverse effects of new roads are immediate, large, persistent, and not amenable to effective treatment. Current and proposed management approaches are inadequate to prevent significant additional damage from roads. In addition to continued degradation, new road construction and reconstruction projects add to the current backlog of road maintenance projects. Construction and reconstruction also is costly and diverts considerable amounts of effort and funds away from other important restoration needs.

If passive restoration is not aggressively pursued throughout the Sierra Nevada, it must be pursued in sensitive areas. These areas include at a minimum:

- aquatic emphasis areas;
- watersheds that contain or feed into habitats with threatened, endangered, depressed, or declining salmonids, amphibians, and other threatened aquatic species;
- roadless areas > 1000 acres or smaller areas adjoining wilderness or other roadless areas;
- biologically important watersheds with existing sedimentation or peakflow/flooding problems; and
- biologically important watersheds with significant hydrologic, mass failure, or other road exacerbated problems.

Additionally, lightly roaded and roadless areas often correlate with aquatic refugia; to maintain and restore these areas there is substantial scientific evidence indicating there should be *no net increase* in road densities in these high priority watersheds.

There also is a very high need to close and abandon a considerable portion of the road network. An aggressive road obliteration program also should be undertaken. Roads in riparian zones, erosive terrain, areas prone to mass failure, and in emphasis watersheds should be prioritized for obliteration. A required level of annual obliteration should be instituted and implemented across the analysis area.

All native surface roads that remain open should be rocked or graveled within two years. All open roads should be surveyed within one year for the need to replace stream crossings that are blocking fish passage and/or are inadequate to pass at least the flow and associated sediment load from a 100-year event. All roads that cannot have such crossings replaced within 5 years should be prioritized for closure and decommissioning.

All remaining open roads should be surveyed to determine the need to improve road drainage, including rerouting road runoff away from streams and stream crossings, and other maintenance needs. Identified maintenance needs should be implemented within two years of the survey, or the roads should be closed, abandoned, and eventually decommissioned.

Surveys also should begin immediately to identify collector and arterial roads that will remain open that are causing high levels of stream damage. These roads should be prioritized for relocation to less damaging areas. Relocation efforts should be aggressively funded, scheduled, and implemented.

Increased road maintenance coupled with travel restrictions can provide some incremental reductions in damage from open roads. These are far less effective measures than abandoning, decommissioning, or obliterating roads. Therefore, they should never be used in lieu of other treatments on extremely damaging roads. They also should not be used as an excuse to keep open or not decommission such roads. Nonetheless, all roads that remain open should have a high degree and frequency of maintenance and inspection for maintenance needs.[10]

However, recognizing that the road system in the Sierra Nevada is extensive and that many high-volume transportation corridors pass through national forests, there will be instances where ecological benefits are subsumed by societal demand for access. In these situations, active and passive mitigation should be pursued vigorously.

[10] Current and proposed management approaches do not require this (USFS, 1999; 2001) and current budgets preclude it (USFS, 2000b). Future budgets also will likely preclude this. A rational approach would be to leave open only those segments that can be reasonably maintained and inspected annually for maintenance needs.

Table 2.5: Roads: Scale and Effects on Sierra Nevada Watersheds

Current Scale of Activity or Condition	**Negative Physical Effects on Watershed Condition or Function**		**Effects of Roads on Fauna**		**Effects of Roads on Beneficial Uses of Watersheds**	
	Increases:	***Decreases:***	***Increases:***	***Decreases:***	***Increases:***	***Decreases:***
• 24,974 miles of forest development roads (arterial = 2,195 miles; collector = 3,492 miles; local = 19,287 miles) • 4,000 to 6,000 miles of unclassified roads • 95,983 to 119,023 stream crossings	• soil compaction • erosion, sediment delivery, sedimentation, seasonal water temperature extremes • flooding • noxious weeds	• soil productivity • bank stability, pool volume • water table elevation, stream incisement, baseflows • stream shading, groundcover, hydric vegetation	• no beneficial effects on aquatic/ riparian species	• habitat quality and quantity of salmonids and amphibians • salmonid and amphibian populations and population connectivity	• storage loss in reservoirs	• useful reservoir life, water supplies in reservoirs

Table 2.6: Roads: Active Ecological Restoration Needs in Sierra Nevada Watersheds

Active Restoration Needs and Measures			
Very High Need For:			
• Road obliteration, decommissioning, culvert removal on closures. • Road drainage improvement, culvert replacement on roads to remain open. • Relocation of major arterials in riparian areas causing resource damage.			
Ecological Risks:			
• Increase (short term) erosion, sediment delivery, and sedimentation. • Noxious weeds may continue to spread via closed roads.			
Ecological Benefits		**Economic or Logistical Benefits**	
Increases:	***Decreases:***	***Increases:***	***Decreases:***
• soil productivity • bank stability, undercut banks • pool volume • water table elevation, baseflows • stream shading, groundcover, hydric species • habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity	• soil compaction • erosion, sediment delivery, sedimentation • seasonal water temperature extremes • stream incisement • surface runoff • rate of spread of noxious weeds	• effectiveness per unit effort of noxious weed control • useful reservoir life, water supplies in reservoirs	• road maintenance costs • road mitigation costs • loss of investment in infrastructure (bridges, etc.), especially in riparian areas • peakflow, downstream flooding and flood damage • storage loss in reservoirs

Table 2.7: Roads: Passive Ecological Restoration Needs in Sierra Nevada Watersheds

Passive Restoration Needs and Measures			
Very High Need For:			
• Elimination of all new road construction, including "temporary" roads. • Elimination of reconstruction except to improve drainage or to reroute existing roads to less hazardous sites. • Closures and abandonment.			
Ecological Risks:			
• Increased erosion and sedimentation from roads with untreated acute drainage problems, undersized culverts, and/or located on unstable areas.			
Ecological Benefits		**Economic or Logistical Benefits**	
Increases:	***Decreases:***	***Increases:***	***Decreases:***
• soil productivity • bank stability, undercut banks • water table elevation, baseflows • stream shading, groundcover, hydric species • habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity	• soil compaction • erosion, sediment delivery, sedimentation • stream incisement • seasonal water temperature extremes • rate of pool volume loss • surface runoff • rate of spread of noxious weeds	• effectiveness of noxious weed control • useful reservoir life, water supplies in reservoirs	• road maintenance costs • construction and reconstruction costs • road mitigation costs • loss of investment in infrastructure (bridges, etc.), especially in riparian areas • storage loss in reservoirs

LOGGING[11]

Extent and Magnitude of Activity

During the last century, logging was one of dominant extractive industries in the Sierra Nevada. Despite this fact, there exist no exact estimates of how many acres of forestland have been logged—or re-logged—over the long term. However, based on estimates of the volume of timber removed from national forests,[12] it is clear that logging and associated roads have impacted a substantial area of the forested portions within Sierra watersheds. Table 2.8 provides logging estimates for eight Sierra national forests over the past decade[13].

Table 2.8: Acres Logged on Eight Sierra National Forests: 1992-2001[14]

Forest	Total Acres	Acres Suitable for Timber Production	% Acres Suitable For Timber Production Logged
Eldorado	677,852	308,000	45%
Inyo	1,946,466	75,000	4%
Lassen	1,060,433	596,000	56%
Plumas	1,173,035	914,000	78%
Sequoia	1,143,562	345,000	30%
Sierra	1,311,913	329,000	25%
Stanislaus	898,121	328,000	37%
Tahoe	869,199	528,000	61%
Total Average	**9,080,581**	**3,423,000**	**38%**

Note that there is wide variability from forest to forest with regard to the number of acres deemed suitable for timber harvest (i.e., areas that support harvestable trees and do not have a

[11] In this report, logging is defined as the anthropogenic removal of live and dead trees, regardless of the purpose. Therefore, logging includes both thinning and all mechanical fuel treatments. Notably, the estimates of logged area provided above do not include the area affected by thinning and fuel treatments. Therefore, the estimates of area logged are a minimum.

[12] The SNFEIS estimates that timber sale offering of both green (live) and salvage (dying, dead, infested, or damaged) trees on national forest lands declined from an average of 743.103 mmbf in the early nineties to 313.750 mmbf by the end of the decade. This volume will rise slightly under the combined direction of the Quincy Library Group EIS and the SNFEIS.

[13] Logging levels in the Sierra peaked in the late 1970's to early 1980's; therefore, this table represents a level of logging activity far below what was occurring twenty years ago.

[14] Data provided by Robert Wolf, Fellow, Society of American Foresters, based on GAO Reports 95-237FS, 99-24, and 97-174.

protected designation [such as wilderness]) and the percentage of those acres logged. Also note that these data do not indicate where on the landscape logging has occurred (e.g., riparian versus upland logging), whether or not there were multiple entries into the same areas within a given time frame, nor the type of logging (e.g., clearcut, group selection, or salvage).

The percentage of riparian areas that have been recently logged tends to be equal to or greater than the percentage of total area recently logged due to ease of access to riparian areas (Rhodes et al., 1994). Therefore, it is probable that more than 38% of riparian areas within logged areas on national forest lands have been logged over the past decade.

Targeted cessation of logging would provide economic benefits. On most of the national forests, logging is conducted at significant taxpayer expense (Talberth and Moskowitz, 1999). The considerable amounts of money spent on logging could be diverted to active restoration needs, or returned to the treasury or taxpayers.

Historic and Ongoing Effects of Logging on Aquatic Resources

Logging significantly increases both surface erosion and mass failure. It has been estimated that logged areas with granitic parent material in mountainous terrain erode at about 2 to 3 times natural rates on a per unit basis (Potyondy, 1991; King, 1993). The mass erosion volumes originating in clearcuts range from about 1 to about 10 times that found in undisturbed areas (Rhodes et al., 1994). Surface erosion increases from logged areas appear to decline to natural levels over time as revegetation occurs (Potyondy, 1991). Although it has been estimated that erosion in logged areas returns to natural levels within 6-10 years, studies in granitic parent materials in mountainous terrain in Idaho found highly elevated rates of mass failures from areas that had been logged more than 10 years prior (McClelland et al., 1997; Rhodes et al., *in process*). Based on a review of available data, USFS and USBLM (1997c) concluded that it is probably impossible to conduct logging without elevating sediment delivery to streams, no matter how carefully it is conducted. Megahan et al. (1992) repeated similar conclusions.

The combined effects of logging contribute to elevated levels of turbidity, sedimentation, fine sediment in channel substrate, and seasonal water temperature extremes, while decreasing cover, channel complexity, pool volume and frequency, and large woody debris (LWD) levels. Logging cannot be considered separately from roads, which are its constant consort in watershed degradation. Logging will always serve to increase or maintain road-related damage to aquatic resources. These factors combine to reduce the survival and production of salmonids, reduce the quality of amphibian habitat, and increase the velocity of population decline and fragmentation.

Recommended Approach For Logging

In order to allow recovery of aquatic resources, logging should be ceased over much of the Sierra until there has been widespread documented recovery of aquatic resources. This is absolutely essential for several reasons, including the relationship between logging and roads and the critical need to significantly decrease the extent of the road network.

Since a full cessation of logging is not likely to occur because of the multiple social demands on the forest that go beyond ecological management objectives, the following is the minimum level of logging restrictions that might allow some recovery of aquatic resources.

First, logging should be eliminated in areas where there is a high level of risk that it will thwart the recovery of important aquatic resources or increase existing levels of degradation. Such areas include:

- roadless areas > 1000 acres[15],
- aquatic emphasis areas[16],
- watersheds with habitat for at-risk aquatic biota,
- biologically important watersheds with already high levels of logging and/or roads,
- watersheds with sedimentation problems, and
- watersheds sensitive to disturbance.

Additionally, no logging should occur in riparian areas[17] that lie outside of these ecologically significant areas.

Second, logging should occur in the absence of new road construction and reconstruction. Assessments that have suggested thinning of dense stands would have benefits to forest health, if properly implemented (USFS and USBLM, 1997c; Franklin et al 2000) repeatedly have stressed that thinning and other fuel reduction efforts should **not** be conducted in

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[15] The USFS provides the following acreage numbers:

LAND ALLOCATION TYPE	ACREAGE
General Forest[a]	2,014,100
Roadless Areas[b]	3,718,000
Wilderness/Wild & Scenic Rivers	2,573,000
Other land allocations	3,229,900
Total acreage of national forest lands in the Sierra Nevada	**11,535,000**

Adapted from SNFEIS, Vol. I, Ch. 2, table 2.7.

[a] This is the area available for commercial timber harvest. This estimate ***does not*** include acreage for salvage logging and other non-commercial logging activities. The bulk of this acreage is concentrated within the QLG project area.
[b] The roadless area sum includes ecologically significant unroaded areas >1,000 acres.

[16] Aquatic Emphasis Areas have a high rate of overlap with other protected land allocations (e.g., wilderness, roadless areas) and roughly occupy 459,000 acres. (Ibid.)

[17] Riparian acreage overlaps with all land allocation types (general forest, wilderness, roadless areas, etc.). The USFS provides an estimate of 1,869,000 acres for the entire Sierra Nevada national forest system based on the formula developed by Menning et al. (1997) in the Sierra Nevada Ecosystem Project Report. The estimate includes not only the area directly adjacent to streams but also steep/unstable slopes and soils. (Ibid, table 2.5.)

roadless areas, but rather should be relegated to areas that have already been roaded and logged (USFS and USBLM, 1997c; Franklin et al., 2000; Brown, 2000).

Third, adequate protections from logging should be adopted to ensure robust biological and morphological functions in riparian areas.

Fourth, thinning and other mechanical fuel reduction treatments should not be extensively implemented, but rather be confined to small experimental areas that are intensively monitored over time. Due to the social need for thinning in urban-wildland interface areas, all thinning in the foreseeable future should be focused on these areas and should not be undertaken in riparian areas or other sensitive aquatic areas.

Table 2.9: Logging: Scale and Effects on Sierra Nevada Watersheds

Current Scale of Activity or Condition	Negative Physical Effects on Watershed Condition or Function		Effects of Logging on Fauna		Effects of Grazing on Uses of Watershed	
	Increases:	*Decreases:*	*Increases:*	*Decreases:*	*Increases:*	*Decreases:*
• 38% of acres suitable for timber production logged from 1992-2001	• soil compaction • erosion, sediment delivery, sedimentation, seasonal water temperature extremes • flooding • stream incisement, gullying • noxious weeds	• soil productivity • bank stability, pool volume • water table elevation, baseflows • stream shading, groundcover, hydric vegetation	• no beneficial effects on aquatic/riparian species	• habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity	• storage loss in reservoirs	• useful reservoir life, water supplies in reservoirs

Table 2.10: Logging: Ecological Restoration Needs in Sierra Nevada Watersheds

Passive Restoration Needs and Measures (Active restoration on logged sites generally is not desirable)			
Very High Need For:			
• Targeted cessation of logging.			
Ecological Risks:			
• There is little to no ecological risk in limiting logging on federal land.			
Ecological Benefits		**Economic or Logistical Benefits**	
Increases:	***Decreases:***	***Increases:***	***Decreases:***
• soil productivity • pool volume • water table elevation, baseflows • stream shading, groundcover, hydric species • habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity	• soil compaction • erosion, sediment delivery, sedimentation • stream incisement • seasonal water temperature extremes • surface runoff • rate of spread of noxious weeds	• effectiveness of noxious weed control • useful reservoir life, water supplies in reservoirs	• logging costs • storage loss in reservoirs

DAMS AND DIVERSIONS

Extent and Magnitude of Activity

The numerous dams and diversions throughout the Sierra Nevada are used for a variety of purposes, including hydroelectric generation and water supply. The CWWR Report estimates that more than 120 hydroelectric operations exist in the Sierra Nevada, with thousands of other smaller diversions. This report also estimated that these reservoirs have a cumulative holding capacity of about 21,000,000 acre-feet, with about 2/3 of that capacity in the foothills of the Sierra Nevada. The SNFEIS stated that there are 175 dams and reservoirs on Forest Service lands in the Sierra Nevada, including 68 projects[18] that will be up for FERC re-licensing by 2045.

The SNFEIS estimated that dams and diversions create more than 150 gaps or blockages that are more than 0.3 miles long in riparian areas. At least 620 miles of these gaps disrupt riparian corridor travel by various terrestrial and aquatic species within the Sierra Nevada national forests (USFS, 2000a), such as salmon.

Historic and Ongoing Effects of Dams and Diversions on Aquatic Resources

Damming a river creates tremendous impacts (Ligon et al., 1995). It severely disrupts stream flow and sediment transport and significantly alters channel conditions (Ligon et al., 1995; Powers et al., 1996; Kondolf, 1997). Together with the indirect impacts of these changes, aquatic biodiversity is profoundly altered.

Dams and reservoirs radically alter streamflow regimes in numerous ways. They typically increase seasonal extremes by increasing peak annual flows while reducing annual minimum baseflow. At the same time, they often reduce the magnitude and frequency of flows expected over longer recurrence intervals. These changes profoundly alter stream conditions, because streamflow magnitude and frequency, along with sediment transport, is one of the greatest determinants of the physical condition of streams and riparian areas, which, in turn, strongly affect aquatic biota (Ligon et al., 1995). These alterations in streamflow typically reduce channel complexity, critical to many aquatic species.

Water released from the dams without sediment causes significant channel erosion for miles below the dams. Some call this phenomenon “hungry water.” This typically results in channel incisement[19] and widening. Even relatively minor incisement can significantly alter groundwater interactions with streamflow.

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[18] This does not include the Humboldt-Toiyabe NF, for which data were apparently unavailable (USFS, 2001).

[19] Channel incisement is the “downcutting” of a stream channel, resulting from natural and unnatural processes. A downcut stream is the mark of a degraded stream.

Further, the “hungry water” usually entrains all finer sediments and transports them downstream toward the ocean. This results in a significant coarsening of substrate (i.e., a predominance or large rocks and boulders). Over time, this can result in a complete loss of gravel suitable for salmonid spawning. Kondolf (1997) noted that gravel was "being artificially added to enhance available spawning gravel supply on at lest 13 rivers in California as of 1992 (cite omitted). The largest of these efforts is on the Upper Sacramento River, where from 1979-2000 over US$22 million will have been spent importing gravel." However, this had highly transient benefits, because the added gravels were washed away within years due to the on-going effects of dams and “hungry water.”

Recommended Approach for Dams and Diversions

Due to their severe and persistent effects on rivers, passive restoration for dams should be fully pursued. Additional dam construction should be prohibited. Storage and diversions should be reduced to the degree possible, and low regime normalization adopted over time.

Although active restoration approaches convey some risks, the status quo conveys greater risk with greater certainty of watershed decline. Efforts should be made to prioritize areas for bypass of sediment. Analyses also should begin to identify the dams with the greatest potential for successful removal. Once prioritized, implementation efforts should be aggressively, but carefully, pursued. Initial restoration efforts for sediment bypass and dam removal should be fully and carefully monitored to provide information to improve future efforts.

Table 2.11: Dams and Diversions: Scale and Effects on Sierra Nevada Watersheds

Current Scale of Activity or Condition	**Negative Physical Effects on Watershed Condition or Function**		**Effects of Dams and Diversions on Fauna**		**Effects of Dams and Diversions on Beneficial Uses of Watersheds**	
	Increases:	***Decreases:***	***Increases:***	***Decreases:***	***Increases:***	***Decreases:***
• Greater than 120 hydroelectric operations; thousands of other smaller diversions • Cumulative reservoir capacity of about 21,000,000 acre feet, (about 2/3 located in Sierra foothills) • 175 dams and reservoirs on national forest lands in the Sierra Nevada, including 68 projects up for FERC re-licensing by 2045	• flow fluctuations • channel erosion, stream incisement, sediment supply from downstream sources • beach loss, shoreline erosion • substrate size • alteration of water temperature regimes	• riparian habitat quality and connectivity • riverine habitat quality and connectivity • downstream sediment supply from upstream sources • bank stability, channel complexity • water table elevation, baseflows	• no beneficial effects on native aquatic/riparian species	• accessible salmonid habitats • habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity • riparian migration corridors	• water storage • hydroelectric power production	• water flows

Table 2.12: Dams and Diversions: Active Ecological Restoration Needs in Sierra Nevada Watersheds

Active Restoration Needs and Measures			
Very High Need For:			
• Dam removal, alter flow operations, and reconnect sediment supplies.			
Ecological Risks:			
• Potential adverse effects on salmonids from increased sediment supply.			
Ecological Benefits		**Economic or Logistical Benefits**	
Increases:	***Decreases:***	***Increases:***	***Decreases:***
• riparian habitat quality and connectivity • riverine habitat quality and connectivity • downstream sediment supply from upstream sources • bank stability, channel complexity • water table elevation, baseflows • accessible salmonid habitats • habitat quality and quantity for salmonids and amphibians • salmonid and amphibian populations and population connectivity • riparian migration corridors	• flow fluctuations • channel erosion, stream incisement • beach loss, shoreline erosion • substrate size • alteration of water temperature regimes	• recreational opportunities (e.g., fishing and river rafting) • commercial fisheries	• coastal erosion, property loss • hatchery fish stocking costs

Table 2.13 :Dams and Diversions: Passive Ecological Restoration Needs in Sierra Nevada Watersheds

<table>
<tr><th colspan="4">Passive Restoration Needs and Measures</th></tr>
<tr><td colspan="4">Very High Need For:</td></tr>
<tr><td colspan="4">• Cessation of construction of dams and diversions.</td></tr>
<tr><td colspan="4">Ecological Risks:</td></tr>
<tr><td colspan="4">• There are virtually no ecological risks in limiting dams and diversions on federal lands.</td></tr>
<tr><th colspan="2">Ecological Benefits</th><th colspan="2">Economic or Logistical Benefits</th></tr>
<tr><th>Increases:</th><th>Decreases:</th><th>Increases:</th><th>Decreases:</th></tr>
<tr><td>• seasonal flow fluctuations

• riparian habitat, habitat connectivity

• riverine habitat, riverine habitat connectivity

• downstream sediment supply from upstream sources

• bank stability, channel complexity

• water table elevation, baseflows</td><td>• beach loss, shoreline erosion</td><td>• effectiveness of restoring spawning gravels</td><td>• costs of dam construction and maintenance</td></tr>
</table>

REFLECTIONS

The protection and restoration of the watersheds in the Sierra Nevada will require:

- elimination of grazing and logging in sensitive areas,
- cessation of most new road-building,
- aggressive reduction of the existing road system,
- modification in operations at many dams and diversions, and
- decommissioning of other dams and diversions.

In sum, restoration of Sierra watersheds will require altering or ceasing the activities that are the primary sources of the degradation. This not only is ecologically sound, it follows common sense. The primary forces that have degraded and continue to degrade the watersheds must be attenuated if the imperiled aquatic species in the Sierra are to recover and the benefits of healthy watersheds are to be regained.

Most of the changes needed are passive; that is, mostly we need to stop doing things that degrade watersheds to allow them to heal by natural processes. Road systems and dams are the exceptions. Roads and dams do not heal themselves, and active restoration, focused on decommissioning the worst roads and re-regulating or removing the worst dams, is an essential part of regaining healthy Sierra watersheds. In addition, for restoration to occur, scarce resources cannot be wasted on projects like fuels treatment that do not address the major sources of watershed degradation, nor on-site specific fixes for problem areas that do not and cannot address watershed-level processes.

Fortunately, most of what watersheds need is not a large monetary investment but rather for us as a society to refrain from damaging them. If we do that, in time they can begin to heal.

CHAPTER THREE: WATERSHEDS AND THE ECONOMY

The preceding chapters make it clear that meaningful restoration of the ecological integrity of the watersheds of the Sierra Nevada will come about only through substantial changes in how humans use (and don't use) the water, land, and other resources. Bringing about the necessary changes in the behavior of those who live in, visit, and admire these mountains from afar invariably will yield not just changes in the ecosystem but in the economies of local communities, California, Nevada, and the nation as a whole.

In the remainder of this report we trace the potential economic impacts likely to result from restoration. Our aim is not to provide a fully quantified accounting of the costs and benefits—both the available data and our budget are too limited. Instead, our goals are more modest: to describe the major types of economic costs and benefits that might accompany watershed restoration; to discuss the potential magnitude of the costs and benefits that might materialize from restoration activities on federal lands in the Sierra Nevada; and to outline the next steps for developing the potential beneficiaries into reliable sources of funding for future restoration efforts.

Our presentation begins, in this chapter, with a short summary of the fundamental relationship between a watershed and the surrounding economy. We employ an analytical framework that recognizes there are many competing demands for watershed resources, that this competition is constantly evolving, and that restoration will reduce the supply of resources for some demands and increase the supply for others. That is, restoration will generate both costs and benefits. The analytical framework we discuss in this chapter also recognizes that the economy is dynamic. It will seek to offset the costs of restoration whenever possible and capitalize on its benefits.

This chapter's discussion of the overall relationship between watersheds and the economy sets the stage for the next two chapters, in which we discuss the potential costs of restoration (Chapter 4) and the potential benefits (Chapter 5). The latter is more extensive than the former, given this report's fundamental focus on understanding the benefits of restoration and setting the stage for finding ways to weave the benefits together to form a foundation for funding a long-run restoration program for the Sierra Nevada.

WATERSHEDS AND THE ECONOMY: AN ANALYTICAL FRAMEWORK

Watersheds interact with the economy primarily through their ability to satisfy the different demands for resource-related goods and services.[1] In the following discussion we present an

[1] It is important to recognize that, along with providing things that humans desire—goods and services—watersheds also produce things they do not. Some have applied the terms "bads" and "disservices" to these undesirable products, such as damage from fires, floods, and so forth. We focus on the goods and services. A description of bads and disservices would be similar.

analytical framework, which we refer to throughout the report, for conceptualizing and examining this demand-supply interaction. The framework rests on the observation that no watershed in the Sierra Nevada can satisfy all the demands for goods and services it provides. Consequently, to understand the potential economic consequences of watershed restoration one must understand how it will affect this competition.

To describe the competition we employ a taxonomy that distinguishes among four types of demands, as illustrated in Figure 3.1. The left side of the figure shows two types of demand for *production amenities*, i.e., watershed resources that help private and public enterprises earn net revenues or increase net wealth. The right side shows two types of demand for *consumption amenities*, i.e., resources that directly influence individuals' economic well-being. The competition among the four types of demand is best understood by assuming that one prevails, and then looking at the consequences for the others.

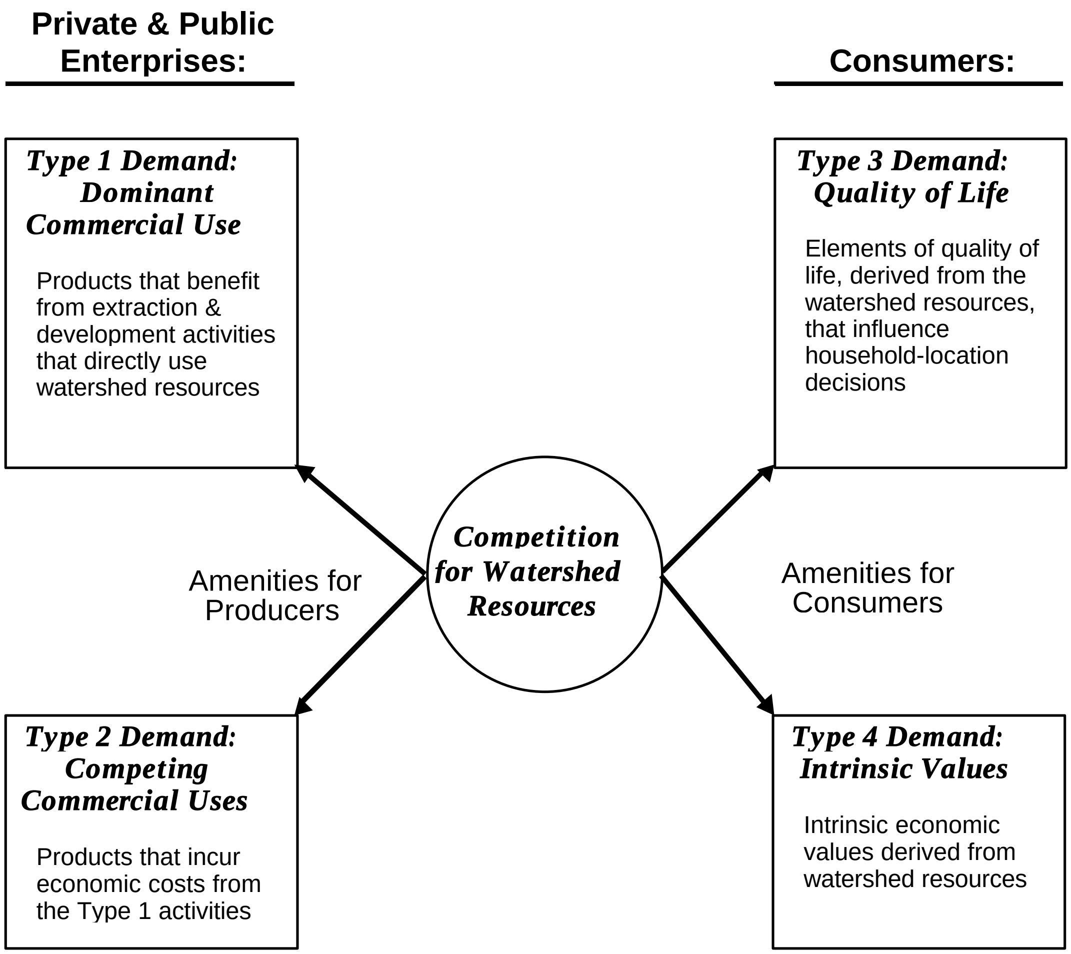
Competition for Production Amenities

Demands for productive amenities usually entail the extraction or development of watershed resources. The term "extraction" embraces crop production, timber production, hydropower generation, grazing, mining, and other activities that chemically, electrically, or physically remove flora, fauna, minerals, or energy from the ecosystem. "Development" refers to the occupation of a site by dams and reservoirs, roads, urban developments, and so forth, as well as intense human activity, such as draining a wetland or changing the floral community, that substantially alters a watershed's ecological processes. Demand for the productive amenities of a watershed comes from "private and public enterprises," which we define broadly to include any groups that sponsor extractive or development activities.

Type 1 Demand - Dominant Extractive and Development Activities. We separate the demands for productive amenities into two groups. We first identify a specific demand and call it Type 1. Type 1 demands represent activities that directly use and deplete the stock of one or more watershed resources. Furthermore, they embody the dominant commercial use of the watershed and are usually associated with a familiar industry, such as farming, ranching, logging, or mining; or with common development activities, such as developed recreation, urbanization, or dam construction. In general, only one industry or activity benefits from a particular use of watershed resources, but sometimes there may be more than one. Dams, for example, may benefit the hydropower, agricultural, and reservoir-recreation industries.

Type 2 Demand - Upon Which Type 1 Production Imposes Costs. Any Type 1 activity can impose costs on other enterprises with competing demands, which we call Type 2. The costs arise when an increase in the output of a Type 1 product, other things equal, reduces the supply of watershed resources available for a Type 2 product, making the latter more costly or scarce than would otherwise be the case. Residential and other developments in the Sierran foothills, for example, can increase runoff from storms, increasing the risk of flooding downstream. Thus, urbanization that increases property values in one location can reduce property values downstream.[2]

Figure 3.1: The Competing Demands for Watershed Resources



Source: ECONorthwest.

We purposefully distinguish between Type 1 and Type 2 products to drive home the importance of competition—within the extractive and development sectors—for watershed resources. This message is important because, too often, the competition for watershed resources is characterized as simply a jobs-vs.-environment contest between an industry seeking to use a resource as a productive input and those who want to protect the environment. By this logic, any restorative program that limited an extractive or development

[2] Our typology may be new, but California history is replete with examples of competing demands for watershed resources in the Sierra Nevada. Early legal controversies, for example, involved farmers who sued upstream mining operations over damage caused when their property flooded and became inundated with mining debris (Larson, 1996).

activity would harm the economy. In most instances, though, any negative impact on such an activity probably would be offset, more or less, by a positive impact on another. Our designation of Type 2 products highlights these tradeoffs.

Competition Directly from Consumers

On the left side of Figure 3.1, watershed resources are economically important because they are inputs in the production of things, such as housing and drinking water, that consumers want. On the right side, though, resources directly contribute to consumers' well-being. There are two types of demand for watershed resources coming directly from consumers: one affects consumers' residential location decisions; the other does not.

Type 3 Demand - Consumption Amenities and Residential Location. Sometimes a watershed produces amenities, such as recreational opportunities, scenic vistas, and healthy environments, that contribute directly to the well-being of people who live nearby. In economic parlance, these are known as consumption amenities. Their contribution to consumers' well-being makes consumption amenities economically important in their own right, but they also influence the location decisions of households and firms, thus adding to their economic interest. We use the term Type 3 demand to represent consumption amenities that influence location decisions.

Whitelaw and Niemi have likened this relationship to a *second paycheck* residents receive by living in a place where they have easy access to amenities, so that the total welfare of residents within commuting distance of the amenities is the sum of this second paycheck plus the purchasing power of their money income. The size of the second paycheck affects behavior in the local and regional economies by influencing household demand for residential location. That location-specific consumption amenities are an important influence in residential location decisions is well documented.[3]

Essentially all of the existing literature on the value of amenities assumes that the amenity value is reflected in wages and prices in the same county or city as the amenity itself. This view is too restrictive for the Sierra Nevada. Here, natural-resource amenities in the foothills attract workers who work, and families who shop, in Sacramento and other Central Valley urban centers. The development of information technology and interstate highways even allows many workers to live in the foothills and commute to the Bay Area . Many more city dwellers commute the opposite direction to take advantage of recreational opportunities in the Sierras. Hence, the Sierra's natural-resource amenities, even though a few hours' drive from California's major cities, plausibly influence the economies of those cities by affecting households' locational decisions, workers' wages, and housing costs.

[3] The early contributions are Rosen (1979) and Roback (1982). For more recent work on this topic see Beeson (1991), Berger and Blomquist (1992), Blomquist et al. (1988), Brady (1995), Brown (1994), Browne (1984), Cooper (1994), Cromartie (1998), Cushing (1987), Figlio (1996), Gabriel et al. (1996), Gottlieb (1994), Greenwood et al. (1991) and Sherwood-Call (1994).

The impacts on wages are especially important. Whenever workers perceive that the *second paycheck* associated with the amenities of the Sierra Nevada is large enough, they will accept smaller *first paychecks* to live in the area. This means that employers can pay lower wages than they would have to pay elsewhere, and the lower wages can increase the competitiveness of local firms relative to firms in other regions. Hence, the consumption amenities that directly benefit workers indirectly become a special type of production amenity for firms that are able to take advantage of the situation. This mechanism allows the natural-resource, consumption amenities of the Sierra Nevada to affect the levels and types of jobs throughout the local and regional economies, including sectors with no direct link to the use of ecosystem resources.

> In effect, residents of an area receive a second paycheck by living where they have easy access to amenities, such as recreational opportunities, scenic vistas, and healthy environments. The second paycheck can influence the locational decisions of households and firms. Thus, the quantity and quality of natural-resource amenities can affect the levels and types of jobs throughout the local and regional economies, including sectors with no direct link to the resources.

Type 4 Demand - Intrinsic Economic Value. The Type 4 demand shown in Figure 3.1 represents the value consumers place on a watershed's intrinsic properties. Intrinsic values, often termed "existence values," do not entail an explicit current use of the resource.[4] They arise whenever individuals place a value on maintaining the existence of a species, scenic waterfall, or other resource for its own sake, or on the prospect that the resource will be useful, for example, to future generations. Actions that increase the robustness of the resources, by preventing degradation of critical habitat for an endangered species or by ensuring the flow of the waterfall, increase the welfare of those concerned about these issues, and actions that degrade the resources decrease this welfare.

Unlike the other three uses of ecosystem amenities that we have discussed, changing the allocation of resources to meet Type 4 demands is unlikely to have any manifest effect on jobs, income, or other indicators of economic activity. Watersheds in the Sierra Nevada may be of intrinsic value to some residents of Miami, Seattle, and other distant places, but the effect of this on economic activity in the region will be small unless it is articulated through the political system, i.e., through federal expenditures to protect the resources. Still, the resource affects the real well-being of real people and for some environmental issues, such as maintaining the biodiversity and integrity of ecosystems passed to future generations, Type 4 values may be very large.

DYNAMIC ADJUSTMENT

Restoring the ecological health of watersheds in the Sierra Nevada will, inevitably, entail changes in how some industries, communities, and households make use of water, land, and

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[4] It could be argued that the life-support services ecosystems provide, thereby making the earth habitable, constitute a fifth type of demand in our typology. To facilitate the discussion, we expand the category of Type 4 products to include this life-support value.

other resources. In some cases, these changes will involve cutbacks in industrial activities such as logging, grazing, and land development, and, understandably, industrial curtailments elicit fears that the changes will be too costly or unfair. Thus, it is important to have a good understanding of how such changes are likely to evolve over time. To forecast how a given local economy will adjust requires not only a detailed knowledge of what that economy currently does, but also knowledge of other things that it might do.

This is the approach we take. We recognize that restoring watersheds in the Sierra Nevada will alter the relationship between these resources and California's economy along two pathways. Along the first, and most direct, restoration will alter the vegetation, hydrology, and other biological and physical characteristics not just in the Sierra but also downstream. These alterations will change the supply of the four types of production and consumer amenities, shown in Figure 3.1.

Along the second pathway, the restrictions will lead to alterations in society's knowledge about the importance of watersheds and the institutions Californians use to manage these resources, and the incentives the institutions create for different types of watershed-management behavior. Information developed during watershed analyses, for example, might improve Californians' understanding of and stimulate a change in their behavior toward these resources. The restrictions might lead to changes in institutions, such as the property-tax system and the willingness of private lenders to extend credit to landowners helping restore watersheds.

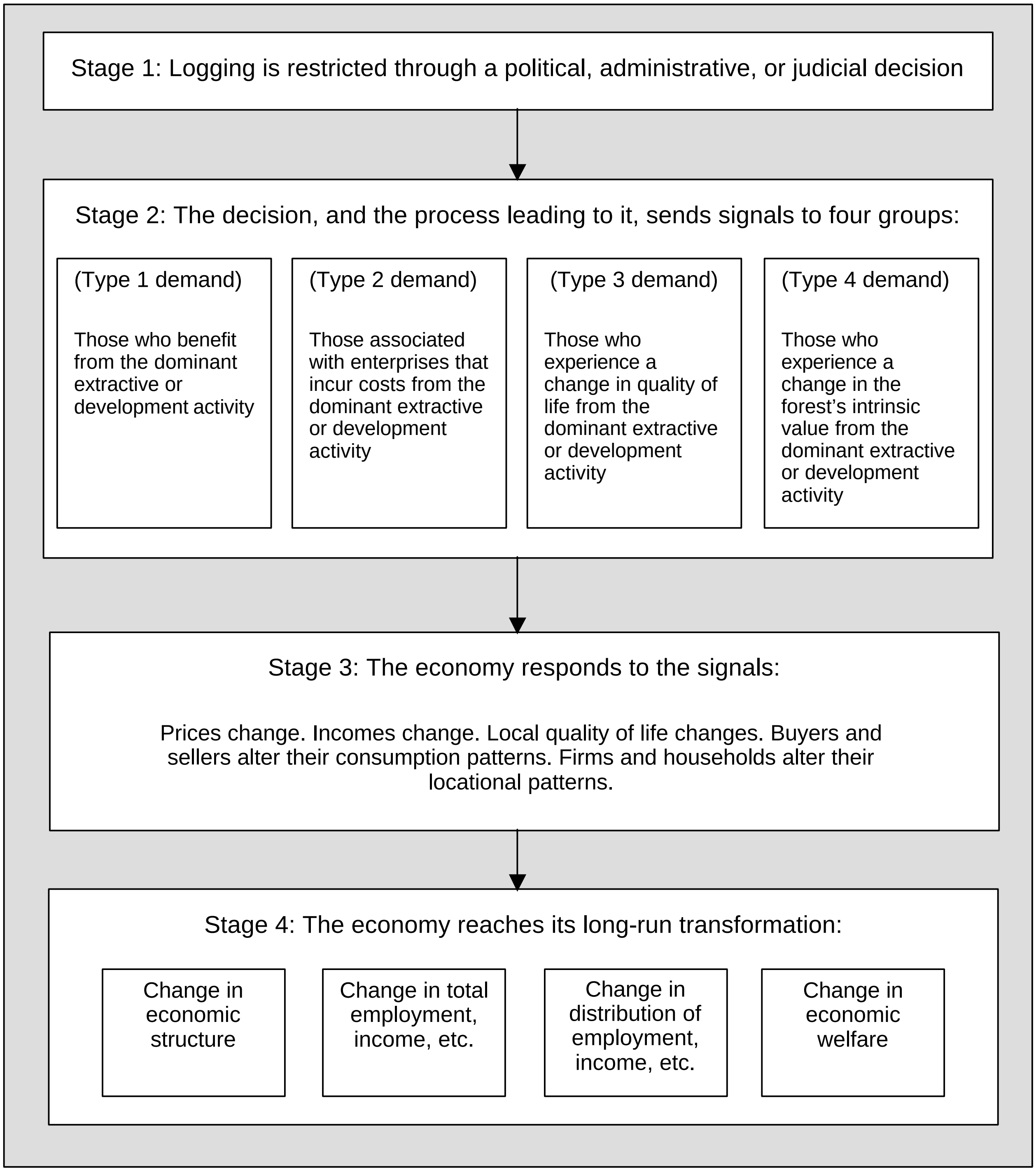
Tracing the Adjustments Over Time

There is no simple way to trace all the changes. If one wants to understand the impacts watershed restoration will have on jobs, incomes, and the like, one has no alternative but to recognize that each worker, household, firm, and community will try to mitigate the impacts it considers negative and to accentuate those it considers positive. In the following discussion we present some of the highlights of the economic impacts.

Implementation of a watershed-restoration program in the Sierra will not have a single, one-time-only impact on the economy. Instead, the economy's response will evolve over time. Whatever the initial, negative impacts, the economy will attempt to mitigate, and whatever the initial, positive impacts, it will try to accentuate.

The evolution will occur in the four general stages shown in Figure 3.2. In Stage 1, watershed restoration activities are adopted and, in Stage 2, this action sends economic signals to the local, statewide, regional, and national economies, indicating a change in the economic role of the state's streams and forests. The signals have four major destinations, represented by the four types of competing demands for the forest resources, shown in Figure 3.1. Although Figure 3.2 shows Stages 1 and 2 occurring as a single, abrupt event, they generally transpire over a longer period.

Figure 3.2: The General Transition Process by Which Watershed Restoration Leads to Changes in the Economy



Source: ECONorthwest.

Stages 3 and 4 of Figure 3.2 illustrate the dynamic character of the economy's response to the restoration activities. In Stage 3, the economy responds with changes in prices or incomes or both. In Stage 4, prices and incomes reach their new levels, and the economy exhibits the long-run effects of watershed restoration. The long-run adjustment may entail feedback loops through which changes in prices and incomes may influence future decisions affecting watersheds.

Feedback To The Ecosystem

As we argue above, changes in watersheds may affect the geographic distribution of the human population as well as its consumption and production behavior. This, in turn, will have effects on the ecosystem which, in turn, will have effects on the economy. Of particular concern is the potential for a feedback loop in which many people see watershed restoration as an enhancement of the consumption amenities available in the Sierra and, hence, increase their demand for residential development, which, if it occurs, would degrade the amenities and reduce their value.

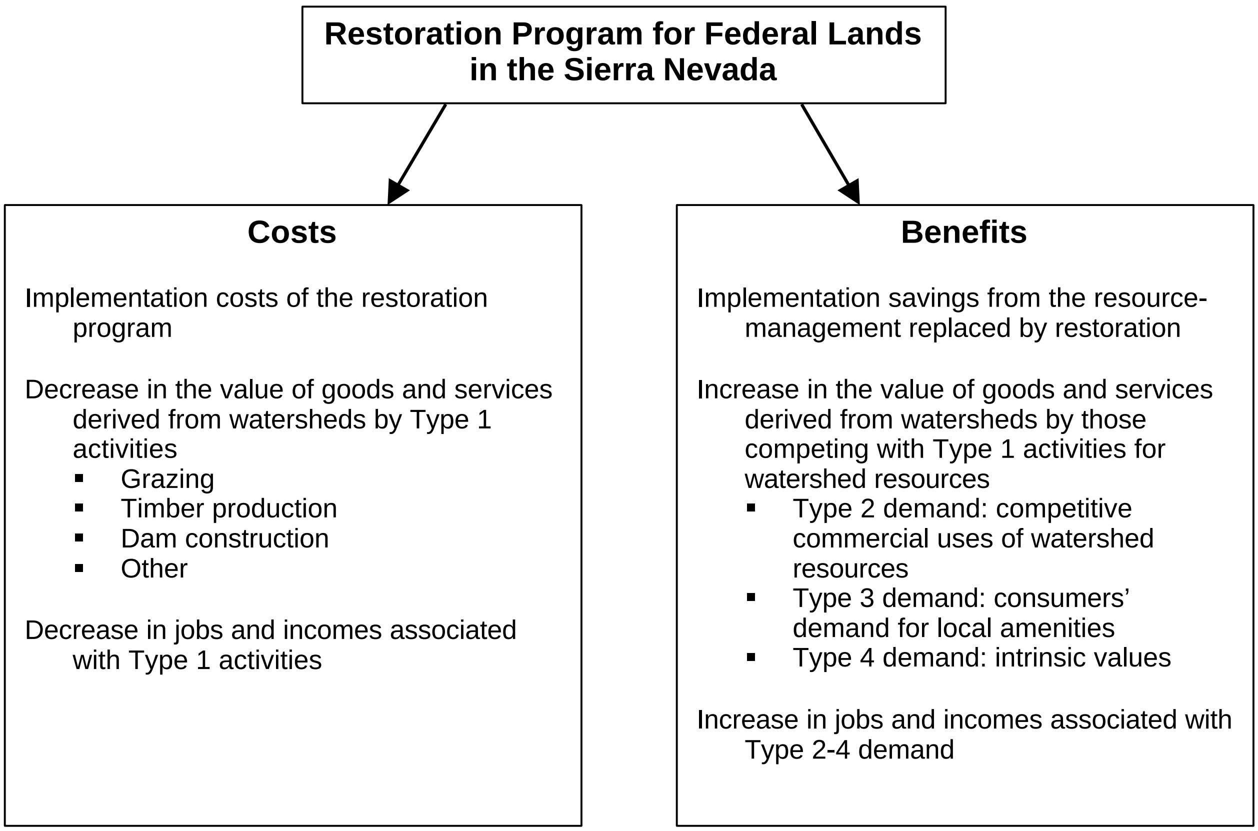
This outcome is not that different from the one that occurs when an extractive or development industry using river or wetland resources does so without having to bear the full costs. If nothing regulates the use of that resource, the demand will exceed the optimal level. If competitive market conditions and fully specified property rights do not exist to provide this regulation more or less automatically, through Adam Smith's "invisible hand," then it must come through deliberate societal management and regulation. If neither approach suffices, then an assessment of the economic consequences of watershed restoration efforts must acknowledge the likelihood that the restoration may sow the seeds of its ultimate failure.

POTENTIAL ECONOMIC CONSEQUENCES OF WATERSHED RESTORATION

The structure of the competing demands shown in Figure 3.1 offers a useful framework for assessing the potential economic consequences of watershed restoration. Restoration would yield both costs and benefits, as illustrated in Figure 3.3. The costs include the costs of implementing a restoration program, decreases in the value of goods and services derived from watersheds, plus decreases in jobs and incomes associated with the use of watershed resources. The benefits are symmetrically opposite: savings realized because the restoration program replaces other resource-management programs; increases in the value of goods and services derived from watersheds; plus increases in jobs and incomes associated with the use of watershed resources. Building on the structure of competing demands shown in Figure 3.1, we assume that restoration will have negative effects on one resource use (Type 1) and positive effects on the other, competing uses (Types 2-4).

Our concern here is with the initial elements of a restoration strategy, described in Chapter 2, which focus on federal lands in the Sierra Nevada. Many of the initial restoration steps point toward preventing further watershed degradation and reversing past degradation from grazing, logging, dam construction, and related activities, such as building roads in riparian (streamside) areas. In the following chapters we discuss the potential costs and benefits of these initial steps.

Figure 3.3: Restoration Will Generate Both Costs and Benefits



Source: ECONorthwest.

REFLECTIONS

Many times, discussions of watershed restoration in the Sierra Nevada appear as a jobs-vs.-environment contest, with opponents claiming restoration will harm the economy and cost jobs, and supporters saying the environment has been damaged and needs to heal. From their different perspectives, the two groups often speak past one another, using different vocabularies and relying on different economic and political institutions to promote their respective causes. The result is a depiction of watershed-restoration proposals as an either/or choice: society can have either a healthy economy or ecologically healthy watersheds, but not both.

We offer a different perspective. The key to our approach is recognizing that the different groups tussling over the management and allocation of watershed resources are, in effect, economic competitors, and that *every* decision about the management of watershed resources in the Sierra Nevada has *both* positive and negative economic consequences. Although some workers, firms, and communities will benefit from decisions rejecting restoration, others will be disadvantaged, and the reverse is true for decisions incorporating restoration. With an understanding of these tradeoffs, the either-or choice can be seen to be a false one. Instead of facing a jobs-vs.-environment choice, society must choose among sets of jobs *and* the environment. At the endpoints are two extremes:

- Healthy watersheds throughout the Sierra and the jobs that accompany them.
- Unhealthy watersheds throughout the Sierra and the jobs that accompany them.

To choose among these endpoints and the innumerable alternatives in between, Californians and others must understand how improving watershed health will affect the composition of jobs and the overall efficiency and prosperity of the economy. This understanding must come from answering questions such as these:

> The key to our approach is recognizing that the different groups tussling over watershed resources are, in effect, economic competitors, and that every decision about management of watershed resources in the Sierra Nevada has both positive and negative economic consequences.

If a restoration program were implemented…

… Which competitors would realize an increase in the degree to which their demands for watershed resources are satisfied? Which ones would realize a decrease?

… What would be the impacts on externalities and subsidies? To what extent would the decrease of some externalities and subsidies outweigh the increase in others? Overall, would the net value of goods and services derived from watershed resources increase or decrease?

… How many new jobs would be generated because of the restoration? How many would be lost? How many would be unaffected?

… What would be the net effect on different groups? To what extent would the potential losers be willing to spend money to oppose restoration? To what extent would the potential winners be willing to spend money to bring it about?

In the remainder of this report, we further investigate these questions. The questions, however, are complex, and watershed resource economics— including water supply issues— in the Sierra Nevada may be the most complex in the nation. Future study will be required to fully elucidate the details. In the next chapter, we delve deeper by looking at how several strong economic forces are likely to shape the competition for watershed resources and, hence, the economic consequences that would materialize if the proposed restoration program were implemented across the Sierra Nevada.

CHAPTER FOUR: POTENTIAL COSTS

Although our primary focus in this report is on the potential economic benefits of watershed restoration in the Sierra Nevada, we fully recognize that implementation of restoration programs will also entail economic costs, both the direct costs of the programs themselves and the indirect costs that will result insofar as restoration restricts some resource uses that otherwise would occur. It will be important to understand these costs before initiating a widespread restoration effort. As the details of the restoration program become more clear, so too will the potential costs.[1] Here, we offer a general discussion of the major types of potential costs, segregating them into three categories:

- implementation costs associated with the recommended restoration program for federal lands;
- a decrease in the value of the goods and services derived from watersheds by the dominant commercial uses of watershed resources, which we call Type 1 demand in Figure 3.1; and
- decreases in jobs and incomes associated with the reduced supply of goods and services to Type 1 activities.

POTENTIAL IMPLEMENTATION COSTS

In this section, we highlight the activities that will generate implementation costs for a restoration program on federal lands in the Sierra Nevada. We provide information useful in understanding the likely magnitude of such costs, but we do not provide actual estimates. The cost information will flow from more detailed restoration program descriptions in the future. Table 4.1 lists the actions that will require funding for implementation.

The costs begin with comprehensive assessments of the watersheds – individually and collectively across broad landscapes – to determine their potential, the extent to which the potential has been compromised, the causes of the compromise, and the most effective restoration strategy. Some assessment work has been completed, through the Sierra Nevada Ecosystem Project (SNEP) and the Environmental Impact Statement recently completed by the Forest Service for the Sierra Nevada Forest Plan Amendment.

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[1] Watershed restoration, like any other significant change in the management of natural resources across landscapes, can generate a wide range of economic costs. These economic costs, for example, may be borne not only by industries, but also by governments, communities, and individuals. We recommend, as outlined in Chapter 6, detailed economic analyses that would address the full range of costs. For more detail on the wide-ranging social connections between natural resources and communities in the Sierra Nevada, see Duane (1999).

Table 4.1: Restoration Actions That May Generate Implementation Costs

Category	Action
Planning	Assess watershed conditions and develop restoration plans
Grazing	Passive restoration: • suspend and/or eliminate grazing in certain areas
Roads	Passive restoration: • cease new construction and most reconstruction • close and abandon some roads
	Obliterate, decommission, and remove culverts on closures
	Improve road drainage, replace culverts on open roads
	Relocate major arterials away from riparian areas
Logging	Passive restoration: • cease and/or reduce logging in certain areas
Dams and Diversions	Passive restoration: • cease new construction or diversions • reduce or eliminate water stored or diverted
	Remove certain dams
	Alter flow operations and reconnect sediment supplies

Source: ECONorthwest and Pacific Rivers Council.

The Pacific Rivers Council (1995) has estimated that 29,200 miles of roads on national forest lands in the Sierra Nevada should be fixed or removed to reduce the amount of sediment they threaten to deliver to streams. Determining which roads require which prescription was estimated to cost about $360 per mile, or $10.5 million total. Implementing the treatment and removal prescriptions was estimated to cost about $1,600 per mile, with a total cost of $46.7 million. Similar treatment and removal is needed on the non-federal lands in the Sierra Nevada. To our knowledge, though, no one has estimated the number of miles, the harm they impose on watershed ecosystems, or the costs of assessing the problems and fixing these roads on non-federal lands.

Similar analysis of all restoration actions will provide estimates of the size and distribution of the implementation costs, which constitute the direct expenses involved in establishing a restoration program. A watershed-level analysis will assign costs basin by basin. In the following sections we discuss other potential costs and benefits arising from watershed restoration in the Sierra Nevada.

POTENTIAL DECREASE IN VALUE OF GOODS AND SERVICES DERIVED FROM WATERSHEDS

Implementation of the restoration program described in Chapter 2 probably would decrease the supply of watershed resources from federal lands to several industries, thereby lowering the value of their output and reducing, in part, the economic well-being derived from the Sierra Nevada. It is difficult, if not impossible, to quantify the exact decreases that legitimately could be attributed solely to the restoration program, insofar as the past decade or so has shown that pressures to decrease traditional industrial uses of federal lands come from numerous sources, such as regulations to protect threatened and endangered species, ensure safe drinking water, and preserve intrinsic values associated with Lake Tahoe and other special places in the Sierra Nevada. Accordingly, our aim is not to quantify the decreases attributable to the restoration program but to describe those that are likely to be most important and to offer some guidance regarding their general magnitude.

Table 4.2: Value of Timber Sold by National Forests in the Sierra Nevada, Annual Average for 1992-99 (in yr. 2000 $)

National Forest	Annual Avg. Volume of Timber Sold[a] (MBF)[b]	Annual Avg. Acres Logged	Value of Timber Sold (in yr. 2000 $)		
			Annual Average[c]	Per MBF	Per Acre
Eldorado	57,191	8,365	12,718,027	222	1,520
Inyo	8,591	1,832	1,706,308	199	931
Lassen	97,443	17,538	18,101,930	186	1,032
Plumas	71,494	15,016	15,717,744	220	1,047
Sequoia	26,172	4,590	5,159,843	197	1,124
Sierra	41,302	1,024	8,757,680	212	8,551
Stanislaus	57,173	6,274	8,879,372	155	1,415
Tahoe	64,827	10,232	7,423,888	115	726
Total	424,194	64,871	78,464,793	185	1,210

[a] Timber sold is the volume of timber harvested.

[b] MBF = thousand board feet.

[c] Value of timber equals total receipts less the Purchaser Road Credit and associated charges.

Note: Part of the Humboldt-Toiyabe National Forest is in the Sierra Nevada, but data for this portion are not available.

Source: ECONorthwest, from data developed by Robert Wolf with U.S. Forest Service and U.S. General Accounting Office data.

One of the most apparent potential decreases is a decline in the amount of federal lands allocated to the production of timber. Table 4.2 shows annual averages for timber sales for eight national forests in the Sierra Nevada sold from 1992 through 1999. Over the eight-year period, the Forest Service sold a total 3.4 billion board feet (BBF) of timber from 519,000 acres. Purchasers, on average, paid $185 per thousand board feet and $1,210 per acre. Actual costs per acre or board foot varied from place to place and over time, but, in general, the numbers in Table 4.2 are indicative of the costs that would be associated with any future decreases in logging that might result from implementation of the recommended restoration program.

Table 4.3: Value of Forage Sold by National Forests in the Sierra Nevada, Fiscal Year 2000

National Forest	Volume of Forage Sold (AUM)[a]	Value of Forage Sold @ $1.35/AUM	Value of Forage Sold @ $8.42/AUM
Eldorado	8,300	$11,205	$69,886
Inyo	26,600	$35,910	$223,972
Lassen	40,400	$54,540	$340,168
Plumas	25,700	$34,695	$216,394
Sequoia	59,400	$80,190	$500,148
Sierra	24,100	$32,535	$202,922
Stanislaus	23,500	$31,725	$197,870
Tahoe	14,900	$20,115	$125,458
Total	222,900	$300,915	$1,876,818

[a] AUM = animal-unit month, the amount of forage needed to sustain one cow, five sheep, or five goats for one month.

Source: ECONorthwest, with data from the U.S. Department of Agriculture, Forest Service (2001).

The livestock industry would also potentially experience a decline in the supply of goods and services from federal lands under the restoration program, insofar as grazing would be restricted from some lands at some times during the year, or would be allowed only with additional animal-management controls to curtail damage to the watershed. Table 4.3 shows data regarding the amount of grazing on the national forests in fiscal year 2000. On average, these federal lands provided 222,900 animal-unit months (AUMs) of forage per year. An AUM is the amount of forage needed to sustain one cow, five sheep, or five goats for one month.

There is considerable controversy over the value per AUM of forage on federal lands and, hence, Table 4.3 shows two values. The lower one, $1.35, represents the price ranchers currently must pay the federal government. The higher one, $8.42, represents an estimate of the 1993 appraised market value (adjusted to 2000 dollars) of forage on federal lands from the crest of the Sierra Nevada westward (U.S. Department of the Interior, 1994a, p. C-2). The actual value of forgone grazing that might result from watershed restoration would vary between these two estimates over time and from place to place.

Other industries also might experience a decrease in the supply of goods and services from federal lands if the restoration program were implemented, but estimating the extent of the decrease is not possible at this time. For example, some nearby private-land development that otherwise would benefit from having ready access to federal lands via existing forest roads might find this access restricted. Some enterprises would be affected by targeted reductions in water storage and diversions. At least conceptually, concessionaires operating in national parks or recreational guides operating on the national forests might find their activities limited if restoration were to limit visitors' access to some streamside areas. Other examples might become more apparent after the restoration programs were initiated.

POTENTIAL DECREASE IN JOBS AND INCOMES DERIVED FROM WATERSHEDS

Insofar as implementation of the watershed restoration program would decrease the supply of resources to the livestock, timber, and other industries, it probably also would decrease the jobs and incomes generated by these industries. As in the previous section, it is impossible at this time to quantify these impacts, and so we describe the types of impacts and offer information about their overall magnitude. We provide a more comprehensive discussion of issues associated with jobs and watersheds in Appendix B.

Over the last two decades the number of jobs generated in California in the timber industry for every million board feet (MMBF) of timber logged from federal lands has fluctuatedbetween about four and seven jobs per MMBF (Stewart, 1996).[2] As a rough rule of thumb, about 6.5 jobs in the timber industry are generated, on average, for every million board feet of timber logged from federal lands (Forest Ecosystem Management Assessment Team, 1993; Yassa and Diamant, 1995). In recent years, eight of the national forests in the Sierra Nevada have produced about 410 MMBF of timber per year, indicating that they have supported about 2,665 timber-industry jobs. At the average rate of logging per acre, shown in Table 4.2, about 24 acres have to be logged each year to support one timber-industry job. Conversely, if a watershed-restoration program removed this amount of land from the total allocated to timber production, timber-industry jobs would decrease by one.[3]

The potential impacts on jobs and incomes in the livestock industry probably would be smaller than those in the timber industry, insofar as the livestock industry is smaller, less labor-intensive, and not highly dependent on federal lands. A 1994 *Rangeland Reform* study of grazing on federal lands found that there were 1,465 individuals or corporations with permits to graze cattle or sheep on federal lands in California and that they depended on these lands to provide 15 percent of the total, annual forage requirements for cattle, and 24 percent for sheep (U.S. Department of the Interior, 1994b). The forage consumed on federal lands in California constituted less than 4 percent of the total for all western states. The study concluded that a 50 percent reduction of grazing on federal lands in all the western states would reduce employment by about 7,239, indicating that a 50 percent reduction on federal lands west of the crest of the Sierra Nevada (2 percent of total grazing on federal lands) would decrease livestock-industry jobs by about 145.

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[2] For this report "timber industry" is shorthand for the lumber-and-wood-products industry, which includes logging, sawmills, plywood mills, and the like. Employment data for the industry refer to Standard Industrial Classification (SIC) 24, as defined by the Office of Management and Budget.

[3]Stewart (1996) points out that market-driven changes, such as technology improvements and industry consolidation, reduced labor requirements in the Sierra Nevada timber industry through the 1980s and 1990s.

With thousands of small diversions and a number of dams, reservoirs and hydroelectric operations in the Sierra Nevada, the effects of selective alterations in some dam operations will become clear when specific proposals are made. A report on the economics of bypassing four large dams on the Lower Snake River in the State of Washington found that there would be both losses and gains as a result of dam breaching. Job losses would occur in dam operation, irrigated agriculture and reservoir-related work, for example, while the number of construction and recreation jobs would grow (ECONorthwest, 1999). Overall, the results were strikingly different than what was commonly assumed. A large number of jobs in dam removal (13,000) and recreation (2,000) would be created. Job losses in agriculture amounted to roughly 2,300 positions, including temporary and part-time workers.

> There is no reason to anticipate that California's response to reductions in logging that might accompany watershed restoration would be any different. The view that the timber industry plays a special role in the economy represents an obsolete sense of how today's economy works. Whatever its economic role in distant decades, the timber industry now plays an increasingly minor role, one that cannot generate the new jobs and higher incomes residents of the Sierra Nevada need if they are to enjoy increases in prosperity along with other Americans.

It is important to recognize that, whatever the industry, estimates of the number of jobs that might be lost because of watershed restoration must be used carefully, for they do not mean that a worker will be thrown out of a job and remain unemployed forever. Job reductions often manifest themselves through attrition, as some workers retire or change jobs voluntarily and employers do not hire anyone to fill the vacancies. Furthermore, nearly all workers who do lose their jobs and seek replacement jobs eventually are successful. In recent years, the success rate has been higher, and the period of unemployment shorter, than in the past.

In this case, however, it is reasonable to anticipate that watershed restoration probably will not cause any worker to lose his or her job. As we explain below, the timber industry is in a deep slump, with lumber prices the lowest in several decades. Low prices mean that supply is large, relative to demand. Hence, to the extent that a restoration program removes some of the supply, producers easily can find replacement supplies and there should be no impact on the industry's current operations or on existing jobs. In the future, as the industry recovers, the industry will likely respond to the restoration programs by creating fewer new job openings.

If, however, watershed restoration causes some workers to lose existing jobs, one should not conclude that the job loss will be permanent. Although data on individual workers in the Sierra Nevada are sketchy, when workers lose jobs they probably experience outcomes similar to those found in national surveys of laid-off workers. The most recent of these surveys revealed that, of those laid off in 1995-96, 83 percent had found work by the February, 1998 survey, and of those, half found a replacement job in less than 8 weeks. More than half of the workers displaced from full-time jobs who subsequently obtained full-time replacement jobs were earning as much or more than they did prior to displacement (Hipple, 1999). Workers in rural areas have fared equally well, or better, than those in metropolitan areas (Hamrick, 1999).

Furthermore, if watershed restoration on federal lands results in job losses, one should not conclude that the affected workers will reside in the immediate vicinity of the national forests. This is especially true of workers in the timber industry in the Sierra Nevada. Although in years past the timber industry was widely dispersed, with local loggers cutting local trees and logs going solely to local mills, the industry is now much more concentrated. Teams of loggers no longer operate solely in their backyards, but can move throughout the region.

It is important, however, to note that each community is distinct.[4] The distinctions among communities in the Sierra Nevada may influence how individuals and communities respond to any changes brought about by watershed restoration programs. The development of major transportation corridors and improvements in information technologies have increased the job opportunities available to those living in many areas of the Sierra Nevada. As a result, communities throughout the region are increasingly tied to metropolitan economies, and a large majority of Sierra Nevada residents live in the foothills within commuting distance of growing Central Valley metropolitan areas. But, there are some communities that remain isolated (Duane, 1996). Developing transition plans for the areas least able to deal effectively with the potential costs of watershed restoration will help ease the transition. These plans are discussed further in Chapter 6.

REFLECTIONS

Rehabilitating watersheds damaged by past human activities and preventing future damage cannot be accomplished without economic costs. Even when restoration entails a passive approach—leaving watersheds to heal themselves—there will be administrative costs as well as costs associated with forgone output and jobs in industries that otherwise would have consumed watershed resources.

Details about the size of the costs and who will pay them will emerge more clearly as the restoration program described in Chapter 2 is scrutinized, debated, refined, and either rejected or implemented. For the most part, these details will be important, but not too controversial. This will not be so, however, for the potential costs to timber-industry workers. Recent experience with similar forest-management issues, in the Sierra Nevada and elsewhere, indicates that these costs can become highly controversial and charged with emotion.

These same experiences also reveal that much of the controversy is likely to stem from a fear that cutbacks in the timber industry will have devastating economic impacts on communities and larger regions. This fear, in turn, often comes from the belief that the timber industry plays a special role in the economy, forming the base supporting all other public and private-sector activities. The theory associated with this belief is called the economic-base theory, according to which, the basic industries warrant special protection because any reduction in them would cause the base to crumble, bringing down all the superstructure sitting atop it.

[4] Appendix B provides information on regional differences and similarities in the Sierra Nevada.

For decades, advocates of logging and other extractive industries on public lands have used the economic-base argument to strike fear into the hearts of public officials, communities, and the public whenever anyone proposed to rein-in logging. For example, one prominent logging advocate and former overseer of the Forest Service concluded that, because of the timber-industry's special role as a component of the economic base, adding a second shift with 67 workers at a plywood mill would be more important to the economy than building a new high-tech plant with 1,000 workers (Beuter, 1995).

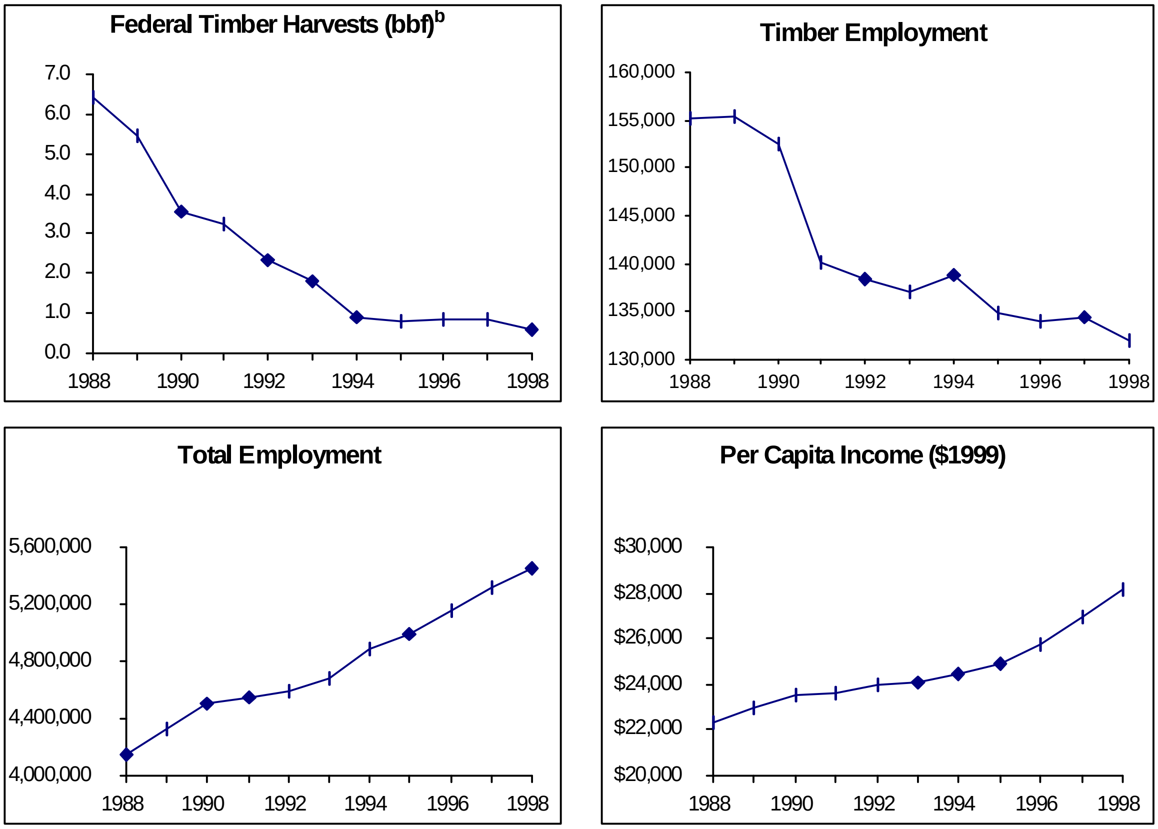
The fundamental flaws in the economic-base theory have been pointed out for decades by economists not aligned with resource-extraction industries (Barkley and Allison Jr., 1968; Courant et al., 1997; Cunningham, 1995; Krikelas, 1992; O'Sullivan, 1993). Proof bearing more directly on the issues associated with watershed restoration in the Sierra Nevada comes from the Sierra Nevada itself. Logging restrictions on federal lands in the early 1990s impacted the timber industry in the Sierra Nevada, and between 1989 and 1993 the number of timber-related jobs declined by 2,254. But total employment grew by 45,363 jobs during the same period. For every timber-related job lost, 20 new jobs became available (Yassa and Diamant, 1995).

The Sierra Nevada's experience is not isolated. In the Pacific Northwest, the economies of Oregon and Washington have responded to reductions of more than 90 percent in logging on federal lands. Before the reductions, countless industry-affiliated economists, political leaders, and others predicted that even a minor drop in logging would, through the economic-base effect, have catastrophic impacts on jobs throughout the economy. Instead, total employment and earnings have grown rapidly, as shown in Figure 4.1.

There is no reason to anticipate that California's response to reductions in logging that might accompany watershed restoration would be any different. The view that the timber industry plays a special role in the economy represents an obsolete sense of how today's economy works. Whatever its economic role in distant decades, the timber industry now plays an increasingly minor role, one that cannot generate the new jobs and higher incomes residents of the Sierra Nevada need if they are to enjoy increases in prosperity along with other Americans.

None of this should be interpreted as trivializing the change endured by individual workers and their families when jobs are lost. Though the change can be easy, even advantageous, for some, it can be gut-wrenching for others. The timber industry, however, is mature, producing commodity products that compete against essentially identical products from producers in a global market. In this context, there is no hope that it will meaningfully generate new, long-run jobs and higher incomes. Thus, if residents of the Sierra Nevada want the national forests to play a larger role in generating jobs and incomes, they will have to look to forest uses other than logging. Watershed restoration offers significant opportunities for capitalizing on these other uses, as we discuss in the next chapter.

Figure 4.1: The Economy of Oregon and Washington Grew Rapidly in the 1990s, Even Though Logging on Federal Lands Plummeted[a]



[a] These are Oregon and Washington data, combined.

[b] bbf = billion board feet

Source: ECONorthwest with data from U.S. Department of Commerce (2000) and Warren (2000).

CHAPTER FIVE: POTENTIAL BENEFITS

Critics tend to be quick to point out the costs of watershed restoration and slow to acknowledge the benefits. We, however, find ample evidence that watershed restoration would generate significant economic benefits, though they may not be as readily apparent to the casual observer as the costs are. In this chapter we outline, in economic terms, the types of benefits that stem from the restoration program described in Chapter 2. We focus on the big questions in order to lay the groundwork for future detailed analyses.

The potential benefits of watershed restoration are, more or less, the mirror image of the costs. Resource-management agencies will realize savings by not incurring costs to implement programs that have been displaced by restoration. Other potential benefits include increases in the value of the goods and services derived from watersheds by users (Types 2-4 in Figure 3.1) other than the dominant commercial users and increases in jobs and incomes associated with these uses.

POTENTIAL RESOURCE-MANAGEMENT SAVINGS

Federal resource-management agencies may realize costs savings in any number of ways from the implementation of the watershed-restoration program described in Chapter 2, but savings associated with five resource-management areas stand out: protection of species; road maintenance; timber sales; grazing; and dam and diversion operation. We describe, in broad terms, how the restoration program may benefit these resource-management areas. We also briefly discuss the implications for fire-suppression and fire-prevention costs.

Preventing species extinction underlies the entire watershed-restoration program. Federal resource-management agencies responsible for preventing extinction, therefore, would save costs insofar as restoration helps species already at risk increase their numbers and prevents the populations of other species from declining to risky levels. There is general agreement among resource managers that habitat restoration facilitates rebuilding populations of at-risk species, and that keeping species from becoming threatened with extinction generally is more cost-effective than allowing them to become threatened and then working to restore them. The recommended watershed-restoration program is consistent with both of these principles.

Passive and active restoration measures addressing roads in the Sierra Nevada will generate savings in construction and maintenance costs. Forest roads on federal lands can be expensive to maintain. Data reported by the U.S. Department of Agriculture, Forest Service (2000 p. 3-22) indicate that, on average, it costs $1,500 per year to maintain each mile of new road on the national forests. Moreover, the Forest Service has not kept up with the maintenance requirements and is looking at a backlog of $5.5 billion total, or $14,250 per mile. The watershed-restoration program recommended in Chapter 2 would enable the Forest Service to avoid some of these costs by ceasing construction of new roads, removing some roads, and rehabilitating others. Rehabilitation would reduce costs, for example, by installing properly-sized culverts as replacements for ones that are so small they frequently become overwhelmed and the overflow washes out roads that subsequently require repair.

Table 5.1: Financial Losses in the Timber-Sale Program for National Forests in the Sierra Nevada, 1995-97

National Forest	Timber Sale Program Losses (Million Dollars)
Eldorado	-19.5
Inyo	0.1
Lassen	-25.6
Plumas	-6.9
Sequoia	-8.1
Sierra	-8.3
Stanislaus	-16.2
Tahoe	-28.0
Total	-112.5

Source: Taxpayers for Common Sense (2000).

By ceasing or limiting logging, the watershed-restoration program could save the Forest Service (and taxpayers) considerable money by forestalling timber sales that otherwise would be net money losers. Table 5.1 reports data, derived from an analysis by the U.S. General Accounting Office, on the losses for the period 1995-97. For none of the national forests listed, except Inyo, did the revenues from the sale of timber cover the costs of selling the timber. The total loss for these Sierra Nevada forests was $112.5 million.

As with sales of timber, grazing on federal lands is a net money loser for the Forest Service and taxpayers and, hence, the watershed-restoration program would reduce these losses insofar as it reduces grazing on federal lands. The losses associated with grazing are not documented as thoroughly as the timber-sales losses, but one rough estimate comes from an analysis conducted by the Congressional Research Service (Cody and Baldwin, 1998), which reported that, although administering the grazing program costs the Forest Service $2.40–3.24 per animal-unit month (AUM), ranchers pay only $1.35. Administrative costs do not capture the grazing program's full costs, which also include subsidies for supplemental feed, predator control, and other concerns. The total cost of grazing on federal lands in the U.S. has been estimated to be $50–200 million per year. The share (2 percent) allocable to grazing on federal lands in California west of the crest of the Sierra Nevada is about $1–4 million annually.

Implementing the recommended passive and active restoration measures for dams and diversions may also result in cost savings for agencies responsible for their operation and maintenance. By not building new dams, for example, construction, operation, and maintenance costs would be avoided, and by not causing ecosystem damage, costs associated with habitat restoration would also be avoided. The removal of aging dams, too, can be less costly than repairing, retrofitting, or replacing them. A study of 25 dam removal projects across the country found that in 44 percent of the cases, cost savings was listed as one of the explicit reasons for implementing the removal project. In several cases, dam removal costs amounted to less than half of the estimated repair costs (American Rivers et al., 1999).

The impact of watershed restoration on fire-suppression and fire-prevention costs is far less clear. Removing forest roads should reduce the likelihood of fires being initiated by humans, which would benefit agencies that expend resources to fight fires. Fewer roads, however, would reduce access for firefighters and their equipment and increase the costs of fighting the fires that do occur.

Some opposition to watershed restoration might stem from a common belief that it would reduce commercial logging and that commercial logging reduces the risk of wildfires and fire-related economic damage. This belief is not, however, supported by the results of current research. In contrast, research shows that fire suppression, in addition to the logging of large, fire-resistant trees, has increased the severity of fires in the Sierra Nevada by fostering the growth of dense small-diameter, fire-resistant species (McKelvey et al., 1996).

More important, the research does not support the conclusion that commercial logging is more cost-effective than targeted "stewardship" logging, aimed at promoting forest health, which might be consistent with the goals of watershed restoration. A report last year by the Congressional Research Service of the Library of Congress concluded that there is too little information to determine conclusively whether commercial logging decreases, increases, or has any effect on the extent and intensity of wildfires. It further observes, "[O]ther treatments, such as pre-commercial thinning, and prescribed burning, are also used to reduce fuel loads, and might be as, or more, effective and efficient at reducing fuel loads as [commercial timber harvesting], depending on the site-specific circumstances" (Gorte, 2000).[1]

POTENTIAL INCREASE IN VALUE OF GOODS AND SERVICES DERIVED FROM WATERSHEDS

The ecological benefits of the watershed-restoration program are outlined in Chapter 2, and now we turn to the associated economic benefits. Restoring the ecological health of watersheds in the Sierra Nevada will enhance the ecosystem's ability to provide some goods and services that are valuable to humans. To help sort through these benefits, we employ the representation of competing demands shown in Figure 3.1, and argue that the benefits would accrue to three groups: some commercial resource-users (Type 2 demand); households whose locational decisions are influenced by the natural-resource amenities of the Sierra Nevada

[1] Cost-effectiveness has long been a stated objective of federal fire policy, yet fire-related programs have also been heavily criticized for exorbitant budgets and a lack of accountability (see, for example, U.S. General Accounting Office, 2002). Hefty fire-suppression costs, faith in fire prevention, and the recognition of the benefits of fire, among other things, have led to many policy reforms (see, generally, Pyne, 1997). Among the objectives of the National Fire Plan adopted in 2001 is targeting fire-prevention efforts near communities most at risk. Research has shown that poor communities and individuals are at the highest risk of economic loss from wildfire, yet fire policy has not developed a mechanism to systematically reduce the linkage between wildfire and poor households and communities (Niemi and Lee, 2001).

(Type 3 demand); and consumers who value the intrinsic properties of the Sierra Nevada (Type 4 demand). We consider each group below.

Commercial Resource-Users (Type 2 Demand)

The recommended watershed-restoration program for federal lands, described in Chapter 2, could produce economic benefits for firms in numerous industries by increasing the supply of ecological goods and services available to them. To illustrate the possibilities, we focus on potential improvements in water quality and late-summer streamflows.

Improvements in the ecological integrity of watersheds on federal lands brought about through passive and active restoration approaches may improve the quality of water in a stream by reducing the amount of pollution that enters the stream and increasing the ecosystem's ability to remove pollutants once they have entered the stream. Reducing human-related sediment is especially important. Sierran watersheds tend to exhibit low natural levels of sedimentation, relative to other regions, but human activities have increased sedimentation above natural levels (Sohrakoff, 1999). Several of the restoration measures would prevent sediment from entering streams: removing and rehabilitating forest roads; reducing logging on steep and unstable slopes; keeping cattle from trampling streambanks; and restoring the ability of natural vegetation in riparian areas to intercept sediment before it reaches streams. Increased shading from the growth of tall trees in riparian areas also can reduce the warming of stream waters by solar radiation. The quality of surface water can be improved as water moves through wetlands or percolates into the soil or gravel bars and reemerges with fewer suspended solids, lower concentrations of dissolved nutrients, and reduced temperatures.

> "Prevention of water quality problems before they occur is much more desirable than remediation of contamination problems. A proactive approach towards prevention of surface water quality problems in general can result in cost savings relative to remediation"
>
> Source: Reetz, 1998, p. 5.

Improving the ability of federal lands to deliver high-quality water is becoming increasingly important to the economy, and especially for municipal-industrial water users. About 45 percent of all surface water in California originates on national forest lands (Sedell et al., 2000). Municipal-industrial demand for water is growing along with population growth, but concerns about quality grow even faster as high-tech industries reduce their tolerance for impurities and consumers become more concerned about the health risks of a growing number of synthetic substances. Municipal water utilities are recognizing that it can be far cheaper to prevent impurities from entering a water supply than it is to allow them to enter and then remove them. San Francisco and other Bay Area cities rely on water flowing from the Sierra Nevada. The Stanislaus National Forest, along with Yosemite National Park, produces 85 percent of San Francisco's drinking water. The water supply is so pure that it is exempt from costly filtration requirements, minimizing water supply costs for the city's residents (San Francisco Public Utilities Commission, 1998).

Watershed Restoration and Municipal Water Supply: New York Case Study

Until recently, the City of New York, which obtains its drinking water from a watershed in the Catskill Mountains, was able to rely on the watershed to deliver water sufficiently pure that it met the water-quality standards of the U.S. Environmental Protection Agency (EPA). Over time, however, the quality of the water diminished as human activity in the watershed introduced a growing supply of sewage, fertilizers, and pesticides and as modification of the watershed's ecosystem impaired its ability to remove pollutants.

Facing a mandate to meet EPA's water-quality standards, New York had a choice: it could invest in restoring the watershed's ability to deliver clean water, or it could allow continued degradation of the watershed and invest in a concrete-based filtration system. A new filtration system was estimated to cost \$6 billion–\$8 billion to build, plus \$300 million annually to operate. Instead, the city chose to invest in restoring the watershed. For an estimated cost of \$1 billion–\$1.5 billion, the restoration program entails buying land and taking other measures to restrict uses that would introduce pollutants into the watershed, plus improving sewage-treatment facilities in the watershed to control pollutants before they are released into the watershed.

By one calculation, within 4 to 7 years the ratepayers' savings on concrete-related costs will have covered their investment in restoring the watershed. This calculation focuses solely on one benefit derived from investments in the watershed: the delivery of high-quality drinking water. Consideration of other benefits, such as enhanced sequestration of carbon by the watershed's vegetation and protection of the region's biodiversity, indicate that watershed restoration makes sense from an economic perspective.

Source: Chichilnisky and Heal, 1998.

The discussion in the text box on this page describes how New York City has confronted water-quality problems. The city concluded that protecting the watersheds providing its water was far cheaper than allowing the watersheds to become degraded and compensating for the degradation by building a new water-filtration system. The estimated savings exceed \$5 billion.

Smaller cities, too, can realize significant benefits by relying on the ecosystem to deliver high-quality water. Salem, Oregon, a city of about 100,000, obtains its water from the North Santiam River, which flows largely from national forest lands in the Cascade Mountains. Almost always, the river water is so pure that the city runs it through a filtration system that involves nothing more complicated than having gravity pull the water through a bed of sand. The system is effective and inexpensive, saving each city resident approximately \$16-\$32 per year by avoiding the costs of a conventional filtration system (Niemi et al., forthcoming), and the water the city delivers to customers has sufficiently high quality that it helped the city attract a silicon-chip manufacturer. The city is very aware that it would have to invest in a more expensive filtration system if the watershed's ability to deliver high-quality water were degraded, and the city is working with the Forest Service and other entities to curtail logging practices and other activities potentially harmful to the watershed.

Water quality also can be important to other resource users. Sediment in streams, for example, can clog channels, reducing their capacity and increasing the risk of future flooding. It also can settle in reservoirs, reducing their capacity to store water for future use, and increasing the maintenance costs for hydropower turbines and other infrastructure. At two reservoirs in the North Fork Feather River owned by Pacific Gas and Electric (PG&E), sediments obstructed the low level outlets, the stream-flow release systems, and the water inlets for operation of the spillway drum gates. Sediment at both facilities was being drawn through the turbines, accelerating wear and increasing maintenance costs. In 1995, PG&E estimated that suspended sediment increased overhaul costs of hydroelectric turbines by $25,000 per unit per year (Sohrakoff, 1999). PG&E identified erosion of stream banks, road cuts, logged areas, burned areas, mine tailings, and grazing lands as the most significant contributors to the stream-carried sediments. The short-term solution to the sediment-related problems was to dredge 620 acre-feet of sediment, but the restricted working area and long haul distances to suitable disposal sites made dredging costs very high. PG&E became involved in an erosion control program in the watershed, where their primary goal was to reduce the rate of sediment accumulation in its hydroelectric reservoirs downstream of the program area. The benefits included reducing future dredging requirements by as much as 50 percent, reducing turbine maintenance, improving water quality, and improving public relations (Harrison, 1991).

Preventing Pollution of Municipal Water Supplies will Become Even More Important in the Future

"Nutrient loading generally increases with runoff, particularly in human-dominated landscapes (citation omitted). Thus, increases in runoff due to increased precipitation [due to climate change] are likely to increase the flows of nutrients into rivers and streams."

"Global and regional increases in air temperature, and the associated increases in water temperature, are likely to lead to adverse changes in water quality, even in the absence of changes in precipitation."

Source: National Water Assessment Group, 2000.

Although there is no study that estimates directly the spillover costs associated with logging and related activities on California's national forests, there is some evidence one can use to estimate the general magnitude of the sediment-related costs. Ribaudo (1986) estimated that, on average, each ton of sediment in streams in the Pacific states imposes costs of $3.25 (measured in 2000 dollars). Other studies, such as Grant and Wolff (1991) and Weaver and Hagans (1994) have estimated the impacts of logging and related activities on the amount of sediment in streams, and found that the impact varies according to location and to the logging techniques employed. Based on 30 years of data associated with a research forest, though, Grant and Wolff determined that clearcutting, alone, can generate an additional ton of sediment per acre, and clearcutting plus roads can generate 3.5 tons per acre per year for about 25 years. These numbers indicate that each acre logged can put in place sedimentation processes that, using a discount rate of 4 percent, have a discounted present value of about $185.These are rough estimates of the average benefits to commercial and other users per acre not logged. The actual amount would vary from place to place, being smaller for acreage where logging would add less-than-average sediment to short streams with few natural and physical assets downstream that are susceptible to sediment-related damage. The benefits would be larger-than-average where conditions are the reverse. There are several reasons to anticipate that, overall, the actual benefits from stopping logging are increasing. The first is that Ribaudo (1986) based his cost estimate on economic conditions in 1986. California's

A Partial List of Offsite Beneficiaries of Erosion Reduction

Recreation

Water storage

Navigation

Commercial fishing

Flooding

Water conveyance

Water treatment

Municipal and industrial withdrawals

Stream-electric cooling

Irrigated agriculture

Source: Ribaudo, 1986.

population and economy already are much larger and, as they grow, so do the benefits of keeping sediment out of streams.

Furthermore, Ribaudo's estimate of sediment-related costs did not take into consideration the risk to human life. In 1996, several people died in a rapidly moving landslide that engulfed a home at the foot of a logged hillside in Oregon (Oregon Board of Forestry, 2001). A follow-up study found that recently logged areas experienced more landslides than other areas (Oregon Department of Forestry, 1999). This example demonstrates that these risks are high, as are the economic benefits of reducing the risks.

Watershed restoration might generate further economic benefits by increasing the supply of water, at least at some times and in some places. The quantity of water in streams is especially important in California, and the integrity of watershed ecosystems affects the supply in complex ways that are not fully understood. Denuding a watershed of vegetation, through clearcut logging, for example, can increase runoff insofar as trees and other vegetation interfere with the buildup of snowpack, intercept runoff, and increase evapotranspiration that returns moisture to the atmosphere. Conversely, restoring vegetation can increase the snowpack by decreasing its exposure to solar radiation and wind. Some have concluded that an extensive series of small clearcuts would strike the best balance between these opposing forces and significantly increase flows from the Sierra Nevada (see, e.g., Kattelmann, 1987).

Others have warned that the net increase in streamflows, if it materializes at all, would be too small to warrant the ecological damage that would result, and that restorative efforts to establish healthy ecosystems would have a greater beneficial impact on stream flows (Rhodes and Purser, 1998). The potential benefits would emerge not from an increase in annual flows but from a shifting of flows to later in the year. PG&E has recognized that improved watershed management may enhance electric generation by increasing base stream flows and decreasing peak flood flows (Harrison, 1991). The snowpack from denuded areas tends to melt faster and earlier, so streamflows are smaller in the late summer, when human demands for water and electricity are high, whereas streams in more natural areas tend to have lower spring flows and to sustain their flows throughout the summer. Further investigation of these issues seems warranted but, insofar as watershed restoration on federal lands would increase flows when the values are highest, this could be a significant economic benefit.

Commercial benefits derived from wilderness also accrue to private industry. Commercial salmon harvesting, hunting and fishing outfitters and equipment suppliers, and the harvest of nontimber forest products such as mushrooms and boughs, support a $130 million industry and employ more than 10,000 people nationwide (Morton, 1999, citing J.H. Johnson). In the Sierra Nevada, some salmon runs have been extirpated; others have not. Watershed restoration could conceivably benefit commercial and recreational fishing to the degree that populations of salmon and other fish are restored.

Households Attracted by Natural-Resource Amenities (Type 3 Demand)

Federal lands in the Sierra Nevada provide numerous, valuable amenities, such as scenic vistas and opportunities for outdoor recreation. Some of the amenities are so outstanding that they attract visitors from all over the globe, and we consider them below, in our discussion of intrinsic values. Others, however, manifest themselves economically by influencing the locational decisions of households, attracting them to the immediate vicinity or to locations, such as the Bay Area, where they can access the amenities more readily than if they located in other states. Access to recreational opportunities in the Sierra Nevada contributes to a high quality of life for many Californians. Quality of life is not just an amenity but, increasingly, a key determinant in attracting workers to California's leading industries (Levy, 1998). To understand the general scale of these amenities, we briefly discuss the importance of recreation on the national forests.

The importance of recreational opportunities can be seen by looking at the results from a 1995 study by the Forest Service, which tallied the contributions to the Gross Domestic Product, or GDP, of different goods and services from the national forests (U.S. Department of Agriculture 1995). GDP, a widely accepted measure of the nation's overall economy and its component parts, is the value of all domestically produced goods and services.

The study focused on the most easily measured goods and services from the national forests and estimated that, by the year 2000, these would contribute $145.1 billion to GDP, about two percent of the national total. Recreation accounts for three-quarters of this contribution, or $108.4 billion as shown in Figure 5.1. Fish and wildlife account for $14.4 billion. In contrast, timber, forage, and minerals account for less than 12 percent of the total value of all goods and services derived annually from the national forests, and timber, by itself, accounts for only 2.7 percent.[2] Range resources provide a very small contribution nationally, yet grazing impacts more acres than any other activity in the Sierra national forests.

Whitewater rafting depends on high quality and high quantities of water. It is a significant recreational use of Sierra Nevada water. The Department of Water Resources estimated that whitewater rafting accounts for 849,000 visitor days per year on rivers within the Sierra Nevada. Approximately two-thirds of the trips are commercial trips, which cost, on average, $87 per day (2000 dollars). The recreational value of the commercial trips alone is $49 million dollars (Stewart, 1996).

The national forests in the Sierra Nevada are among the most valuable, from a recreational perspective and, hence, they are among the most attractive to households seeking to avail

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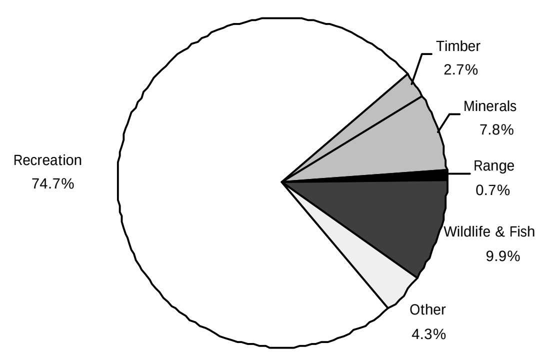
[2] Figure 5.1 tells only part of the story, for it does not include three of the most important services the national forests provide: (1) the delivery of clean, cool water; (2) the sequestration of atmospheric carbon; and (3) the provision of unroaded, wild areas. Rough estimates indicate these three services, together, exceed the total value represented in Figure 5.1 (Niemi and Fifield, 2000).

themselves of the recreational opportunities. The watershed-restoration program recommended in Chapter 2 should increase the value of the recreational services available on the national forests in the Sierra Nevada and, hence, make them an even stronger attractant for households. In particular, by removing forest roads and facilitating the return of some lands to a more natural condition, the program should increase opportunities for unroaded, wild recreation.

Many recreationists find that the value of their recreational activities on national forests is enhanced when they take place in wild and unroaded areas, insofar as these areas offer large, undisturbed landscapes that provide privacy and seclusion. A recent study of federal lands in the Columbia River Basin found that the value recreationists placed on activities taking place in a wilderness area were roughly double the values of similar activities on federal lands outside wilderness areas (Haynes and Horne, 1997). It seems reasonable to anticipate that a similar increase in recreational benefits would occur in the Sierra Nevada wherever the restoration program described in Chapter 2 recreated or protected recreational opportunities associated with unroaded, wild lands. Walsh, et al. (1988) reviewed relevant studies and concluded that the net economic value of wilderness recreation ranged from about $15 to $150 per day, with an average value of $35 per day (2000 dollars).

Figure 5.1: Contribution of Goods and Services Produced by the National Forests



Note: Total Value equals $145 billion (1999 dollars).
Source: U.S. Department of Agriculture (1995).

Intrinsic Values of the Sierra Nevada (Type 4 Demand)

Unroaded, wild areas also have high intrinsic values. Americans generally see unroaded areas as national assets that are to be protected. In a nationwide poll conducted in January, 2000, by American Viewpoint, 76 percent of the American public supported the protection of roadless areas in national forests from logging, road construction, and other development (DiVall and Onorato, 2000).

> **Households Say They Are Willing to Pay for Watershed Restoration**
>
> The Platte River in Colorado has been severely degraded, but proposals have been developed to restore five ecosystem services: dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation. Households were surveyed to estimate the overall willingness to pay for the increased services through a higher water-utility bill. Results indicate that households were willing to pay an average of $21 per month, or $252 annually, for the enhanced ecosystem services. The lower bound of the estimated willingness to pay for these services exceeded the costs of two necessary steps for restoring the ecosystem services: retiring land from farm production or leasing water from irrigators, and keeping the water in-stream.
>
> Source: Loomis, et al., 1999.

Measuring the special values of wild and unroaded areas, in the Sierra Nevada or elsewhere, is difficult because there are no prices or other market data typical of goods and services traded in the private sector. As a rough indicator of these values, though, it is useful to consider the findings from an economic assessment of goods and services derived from 78 million acres of federal lands in the Columbia River Basin (Haynes and Horne, 1997). The existence value of unroaded areas was roughly equal to the total value of all recreation occurring on federal lands.

In the absence of a more detailed estimate, it seems reasonable to apply this finding here and conclude that the existence value of protecting unroaded, wild areas on the national forests of the Sierra Nevada is equal to the value of all recreation occurring on the national forests. Thus, insofar as the watershed-restoration program protects or restores unroaded, wild areas, it will protect or restore an economic benefit significantly more important than just the recreational value associated with those lands.

Other intrinsic values will materialize as the watershed-restoration program reduces the risks of extinction for species already listed as threatened or endangered, as well as those that might be listed in the absence of restoration. There is no estimate of the economic value of preventing extinctions, although numerous polling results show strong public support for doing so.

It is also possible that the watershed-restoration program will increase the sequestration of carbon on federal lands and help curtail global warming. While the research on this topic has led to disagreement over the extent of this possibility, we include a description of the potential benefits based on research findings.

Several atmospheric gasses, including carbon dioxide, hold heat next to the earth, much like glass holds heat in a greenhouse. Mounting evidence indicates that increases in these gasses—for example, carbon dioxide produced by burning coal and oil—is warming the atmosphere and the earth's surface. One potentially effective way to sequester carbon is to grow trees, converting carbon dioxide into wood fiber. When trees grow, they store carbon dioxide as wood; when they are cut, they cease to absorb carbon dioxide and begin to return the stored carbon to the atmosphere.

Table 5.2 shows an estimate, developed by the Forest Service, of the carbon currently sequestered in softwood trees in the national forests of California (Haynes, 2000). There are approximately 31.8 million cubic feet of wood fiber on these national forests and, at roughly 30 lbs. of carbon per cubic foot of fiber, this translates to 477.1 million tons of carbon. There is great uncertainty about the value of sequestered carbon. But it is useful to examine a range of values—from a low of $6 per ton to a high of $65 per ton. The former is the value for stored carbon that two trading companies have established (Comis et al., 2001). The latter is the value used by Forest Service economists, based on data from the Environmental Protection Agency, to estimate the value of carbon sequestration in the Columbia River Basin (Haynes and Horne 1997). It represents the marginal value of changes in the amount of sequestered carbon and probably overestimates the average value of the existing inventory of sequestered carbon, but by how much is not known. With these estimated values per ton, the current stock of sequestered carbon on the national forests of the Sierra Nevada has a value between $2.9 billion and $31 billion.

Table 5.2: Carbon Sequestration on the National Forests of the Sierra Nevada

Wood-Fiber Inventory (million cu. ft.)	31,804
Stored Carbon[a] (million tons)	477.1
Value of Stored Carbon	
@ $6/ton	$2.863 billion
@ $65/ton	$31.009 billion
Additional Wood Fiber by 2050 (million cu. ft.)	
with Logging	26,455
without Logging	32,717
Additional Stored Carbon by 2050 (million tons)	
with Logging	397
without Logging	491
Incremental Carbon Storage without Logging	
Quantity (million tons)	94
Value (@ $65/ton)	$6.105 billion

[a]Assumes 30 lbs. of carbon per cubic foot of wood fiber.

Source: Data provided by Richard Haynes, USFS Pacific Northwest Research Station.

Table 5.2 also shows an estimate of the additional amount of carbon that might be sequestered by softwood trees on the national forests by 2050, with and without logging. The bottom line shows that, with logging planned by the Forest Service at the end of the 1990s, some logging would occur, the inventory of wood fiber on the national forests of the Sierra Nevada would increase by 26,455 million cubic feet, and the amount of stored carbon would increase by 397 million tons. If the planned logging did not occur, however, the forests would accumulate an additional 6,262 million cubic feet of fiber and an additional 94 million tons of carbon. At an estimated value of $65 per ton, the additional carbon stored without logging would be worth $6 billion. In this instance, it is appropriate to use $65 per ton as the value of the additional stored carbon, because eliminating logging would result in an incremental increase to the world's stock of stored carbon.

The carbon stored in the wood fiber of trees is only a part of the total carbon sequestered by a forest. Roughly half of a forest's carbon is stored in the soil and forest floor, the other half in trees, woody debris, and the understory. One report estimates that the average carbon storage per unit of timberland in California is about 22 kilograms (48.5 lbs.) per square meter (Turner et al., 1995, p. 430).

POTENTIAL INCREASE IN JOBS AND INCOMES DERIVED FROM WATERSHEDS

The watershed-restoration program for federal lands could generate new jobs and incomes through two mechanisms. In one, new jobs would materialize in industries that realized an increase in the supply of producer amenities from restored watersheds. The outdoor-recreation industry might expand in response to the increased supply of unroaded wild areas, or growing populations of native fish available to anglers. Commercial and industrial customers of municipal water systems might experience lower operating costs and convert these into new jobs and/or higher incomes for existing workers, insofar as watershed restoration helps municipal water utilities enjoy lower water-treatment costs.

In the other mechanism, jobs would materialize if watershed restoration increased the supply of amenities attractive to consumers, more households decided to locate in or near the Sierra Nevada, and industries expanded accordingly. Some industries might expand to take advantage of the larger labor pool, others to take advantage of the larger consumer market.

It is impossible at this time to quantify the impact on jobs and incomes that might materialize through either mechanism. Considerable evidence indicates, however, that if watershed restoration noticeably affects public perceptions of the supply of unroaded, wild forest, then the impact on jobs could be considerable. Throughout the West counties and communities with outstanding natural resources, more wild areas, and a high quality of life for their residents experience faster growth in employment and incomes (Cromartie, 1998; Drabenstott and Smith, 1996; Rudzitis and Johansen, 1991; Southwick Associates, 2000). In a recent statistical analysis of rural counties in 11 western states including California, the researchers found roadless areas were positively correlated with growth in income and employment. They also found that employment and income in non-metropolitan counties have grown faster in those counties with a larger portion of their land base in roadless areas (Southwick Associates, 2000).

REFLECTIONS

The benefits of watershed restoration will probably be less visible than the costs. It will be easier to see the expenditures on restoration than the savings in expenditures on the logging, grazing, and other programs that restoration displaces, or the avoided costs that otherwise would be incurred to cope with threats to at-risk species and the worsening of other environmental problems. Curtailments in logging and grazing, along with the reductions in associated jobs and incomes, will be easy to recognize relative to the benefits of cleaner water and a healthier ecosystem.

Despite their relative invisibility, the discussion in this chapter makes it clear that restoring the ecological integrity of watersheds in the Sierra Nevada would generate widespread, significant economic benefits. Furthermore, there are compelling reasons to believe that these benefits would grow over time, relative to the costs. This conclusion rests on observations about the extent to which the relationship between watersheds and the economy is influenced by several powerful trends. One of these is rapid population growth in the Sierra Nevada region. Population has been growing faster here than in the rest of California and is expected to continue to do so, reflecting the increasing demand for the region's high-quality amenities and low cost of living relative to other areas of California. Watershed restoration should reinforce this trend, insofar as it would enhance several important amenities from federal lands, such as the supply of unroaded lands and the quality of water in streams originating on federal lands. Restoration also would bolster efforts to control the costs of providing public services to growing communities, primarily because the cost of keeping water supplies clean is lower than that of allowing water to become polluted and then incurring costs to remove the pollution.

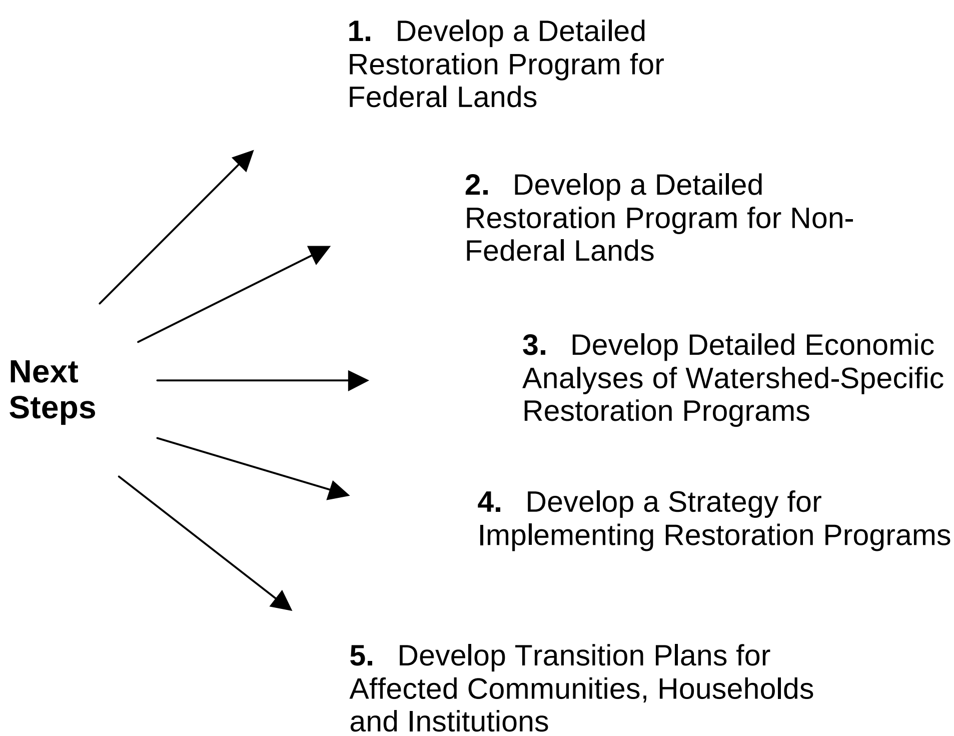
Another related trend expected to increase the future benefits from restoration is the increasing integration of metropolitan and non-metropolitan economies. In the past, the Sierra Nevada contained numerous, isolated communities, whose economic well-being depended largely on their respective ability to produce food, lumber, and other commodities. The earnings of workers, especially in manufacturing, constituted the bulk of household incomes. This structural underpinning of local economies has eroded, though, as services have become more important than manufacturing; pensions and other non-labor sources of income have become more important than workers' earnings; and improved transportation-communication systems have expanded the effective commuting radius around metropolitan centers. In short, communities in the Sierra Nevada now are far less isolated economically than in the past.

These changes have fundamentally altered the process of economic development in the Sierra Nevada region. In the past, it made sense for an isolated community to believe it could increase the incomes of its citizens by converting local natural resources into commodities, by converting forests into lumber, for example. Now, though, such actions yield diminishing returns. Many communities are finding that, rather than exporting their natural resources, in the form of commodities, to distant consumers, they are better off importing consumers to enjoy the natural resources in place. With careful planning and commitment, the watershed-restoration program described in Chapter 2 can reinforce the economic development efforts of communities that have opted to capitalize on these changes in the relationship between the environment and the economy.

CHAPTER SIX: NEXT STEPS

In the previous chapters we take the first steps toward developing a long-run, financial foundation for watershed restoration in the Sierra Nevada. In the first two chapters, we provide an overview of the extent to which the ecological health of watersheds in the Sierra Nevada has been degraded, and we outline a restoration program for preventing further degradation and rehabilitating past degradation on federal lands, where the available data are most extensive and the opportunities for implementing restorative actions are most immediate. In Chapters 3-5, we demonstrate that implementing an ecologically sound restoration program would yield considerable economic benefits, and the economic costs would be lower than is generally anticipated. These conclusions arise largely because the economy increasingly considers the ecological services that healthy watersheds can provide, such as clean water and high-quality natural-resource amenities, to be more important than the commodities, such as timber and livestock forage, that historically have been extracted from watersheds in a manner harmful to the natural ecosystem.

Figure 6.1: Next Steps



Source: ECONorthwest.

In this chapter, we look forward and offer our recommendations for the next steps. They fall into the five categories shown in Figure 6.1. The first one entails refining the contents of Chapter 2 into a more detailed, watershed-specific, restoration program for federal lands, while the second entails expanding the restoration program to embrace non-federal lands. Next Step #3 involves building the economic rationale for the restoration program through a set of watershed-specific analyses detailing the costs and benefits of restoration. The economic analyses involve identifying the winners and losers and describing the extent to which the benefits and beneficiaries might be tapped to pay the costs, provide incentives, and compensate those who would incur extraordinary costs. Next Step #4 builds on the previous ones and entails developing a financial, political, and legal strategy for bringing about a meaningful increase in watershed restoration in the Sierra Nevada. Finally, Next Step #5 involves developing transition plans to enable affected communities to capture the benefits of watershed restoration.

NEXT STEP #1: DEVELOP A DETAILED RESTORATION PROGRAM FOR FEDERAL LANDS

The first step is to select a watershed as a test case for implementing the restoration program described in Chapter 2. This will provide site-specific guidance for further restorative actions on federal lands throughout the Sierra Nevada, help identify priorities for restorative actions within each watershed, detail the budgetary and other requirements for implementing the program, and quantify (as far as the available data will allow) the expected impacts on watershed resources.

As detailed in Chapters 1 and 2, the first step in developing a detailed restoration program for federal lands in the Sierra is to conduct watershed analyses at appropriate scales (regional, basin, and sub-basin). Such analyses should:

- Identify the areas in need of protection, including riparian areas, unstable slopes, refugia, and other sensitive areas.
- Characterize the natural physical processes (e.g., flow regime, sediment delivery, etc.).
- Identify the forces and practices that cause watershed degradation.
- Assess the reversibility of those forces and practices.
- Define and prioritize the suite of restoration needs, first the passive restoration needs (e.g., altering land management practices and dam operations) and then the active ones (e.g., retiring roads, removing dams, building fencing, etc.).

Scientific teams that should include at least one expert in each of the following fields should conduct watershed analyses: aquatic ecology, hydrology, geomorphology, and biology. Once watershed analysis is completed, a schedule of prioritized restoration activities along with an approximate allocation of resources (personnel, equipment, etc.) should be incorporated into ongoing and incipient land management plans.

NEXT STEP #2: DEVELOP A DETAILED RESTORATION PROGRAM FOR NON-FEDERAL LANDS

The second step will entail extending the analysis in Chapters 1 and 2 to include non-federal lands. Non-federal lands in the Sierra Nevada lie at lower elevations and embrace many different land and water uses. The portions of watersheds lying below federal lands face different challenges and have received less attention in broadscale scientific assessments of the region.

Developing a restoration program for non-federal lands will require an approach radically different from the one outlined above. First, private lands in the Sierra Nevada, especially in cities and townships, provide a different societal function than public lands. Second, most private lands are developed or utilized in such a way that watershed restoration cannot be achieved at the scale outlined in this report. Lastly, oversight of the use and development of private lands involves more numerous and diverse players, including state and federal agencies, county commissions, local planning agencies, neighborhood associations, and others.

For watershed restoration on private lands, we advocate adopting the approach of the Sierra Nevada Ecosystem Project (SNEP). That is, convene interdisciplinary teams of experts (e.g., experts from the physical and social sciences, economists, etc.) to outline a restoration strategy at the appropriate ecological scale. As watershed boundaries most often do not mimic land ownership patterns, this approach will require coordination between counties, municipalities, and individual landowners in order to succeed. Or, as the SNEP authors state: "Ecosystem management involves various activities…[that] will need to be modified to fit the particular circumstances and the context of the community" (University of California and SNEP Science Team and Special Consultants, 1996, p. 43). In the context of watershed restoration, these activities include but are not limited to:

- Monitoring of biological, ecological, social, and economic functions;
- Maintenance and restoration (e.g., erosion control);
- Protection and maintenance of water quality and quantity;
- Providing continuing opportunities for recreation and tourism (e.g., fishing, kayaking, etc.); and
- Protection of reserves (i.e., refugia) (University of California and SNEP Science Team and Special Consultants, 1996, pp. 43-44).

NEXT STEP #3: DEVELOP DETAILED ECONOMIC ANALYSES OF WATERSHED-SPECIFIC RESTORATION PROGRAMS

This step will entail tracing the linkages between the economy and the watershed-specific restoration programs to be developed in the previous steps. The products of this effort would become the basis for subsequent efforts (in Next Step #4) to devise strategies for tapping the benefits and beneficiaries to underwrite the costs of restoration and provide economic incentives for private landowners.

This effort must cover the costs as well as the benefits, and the groups that potentially would bear the costs as well as those that would reap the rewards. The analyses of costs must consider both implementation costs and the value of resource uses that would be forgone if the restoration program were implemented. Having the proponents of restoration develop realistic estimates of these costs will be essential, both to give the restoration proposals credibility and to facilitate a more meaningful dialogue with different interest groups. Past experience indicates that such dialogues can easily flounder if the proponents of restoration cannot quickly respond to fears that restoration would have devastating impacts on communities and traditional industries. In some cases, restoration might result in extraordinary costs for some groups. For example, removing barriers and allowing streams to flow over floodplains in one place might increase the flood risk there while it reduces the flood risk lower in the watershed and generates other ecological benefits. Identifying groups that might bear extraordinary costs under the restoration program will be important, both to improve understanding of equity concerns associated with restoration and to mitigate opposition to a proposed restoration program that might arise if it were to be seen by the public as having callous, unfair impacts on some groups.

Although the analyses of costs will be important, the primary focus of this step will be on the benefits. As scientists develop an ecologically sound restoration program for a given watershed, economists will trace the linkages between the watershed and the economy to determine where the economic benefits of restoration might manifest themselves. They then will evaluate alternative tools for capturing some of the benefits so the funds can be used to pay for public and private restoration activities.

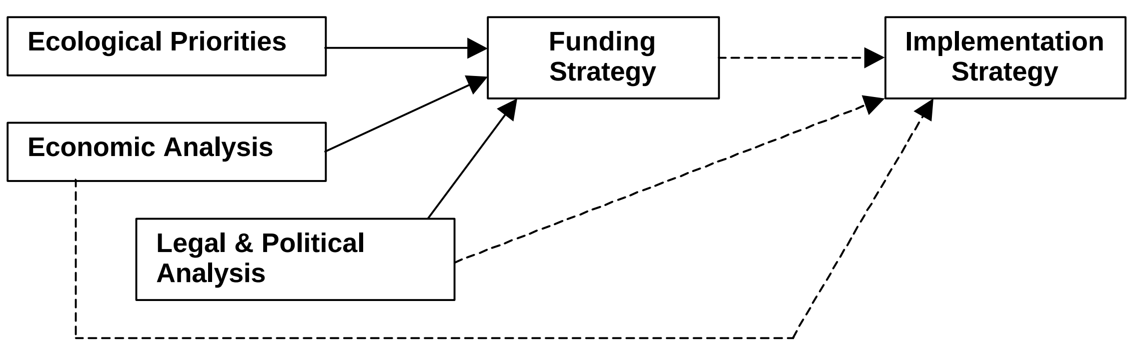
Table 6.1, which is located at the end of this chapter, illustrates some of the potential linkages and tools for capturing the benefits. The first entry shows that, if restoration results in cleaner water in streams—by removing forest roads that generate sediment, for example—the economic benefits might manifest themselves as lower costs for downstream, municipal-industrial water users to filter sediment from their source water; improved recreational opportunities for anglers and other recreationists; increased property values for owners of properties adjacent to the stream; lower costs for downstream landowners to unclog channels, ditches, and reservoirs; and lower operating-and-maintenance costs for dam operators and industrial users of water. Part of these benefits conceivably could be captured through a surcharge on water-utility rates, increased fees for recreational permits, increased collections from property taxes on properties whose values rise because of cleaner water in streams, and direct payments from various beneficiaries to fund restoration.[1]

Similar manifestations of benefits and tools for capturing of some of the benefits would materialize for the other ecological changes shown in Table 6.1. Note that the tools listed in Table 6.1 are identified for illustrative purposes only. They are not recommendations. Specific recommendations would emerge only through careful examination of the watershed-economy linkages for individual watersheds and watershed-specific restoration proposals. Each case would require its own tool(s) for capturing some of the benefit and dedicating it to restoration. Similarities among the watersheds, economic issues, data sets, and so forth indicate that many aspects of the economic analysis probably will vary little as one moves from one watershed to another. Each watershed probably would require its own economic analysis, however, because there are some important differences among some watersheds, such as those with large urbanized populations vs. those without. In addition, watershed-specific analyses will be useful for building local support for (and addressing local opposition to) restoration.

NEXT STEP #4: DEVELOP A STRATEGY FOR IMPLEMENTING RESTORATION PROGRAMS

This step will entail combining the ecological and economic products from the previous steps with some solid legal and political analysis to develop a strategy for implementing watershed restoration programs for the Sierra Nevada. Figure 6.2 outlines the process.

Figure 6.2: Developing an Implementation Strategy



Source: ECONorthwest.

[1] The theory behind capturing the economic benefits is sound, but the application of such techniques would be subject to the confines of state and local laws. Property tax restrictions, such as California's Proposition 13, are constraints that will have to be taken under consideration when formulating specific proposals.

This step would produce two key products. The first would be a funding strategy that shows the highest ecological priorities for restoration, evaluates the alternative tools for capturing some of the economic benefits from restoration, and identifies the critical legal and political steps that must be taken to secure adoption of these tools.

The second product would be an overall implementation strategy for the proposed restoration program. It would augment the funding strategy with an implementation roadmap, a communication plan, a budget, a schedule, and a description of the responsibilities of different groups and individuals who will be responsible for implementation. This implementation strategy would include transition plans described in Next Step #5.

NEXT STEP #5: DEVELOP TRANSITION PLANS FOR AFFECTED COMMUNITIES

This step entails developing transition plans for affected communities, households, and institutions. The transition plans would help affected groups determine the extent to which their activities would have to change to accommodate restoration and identify opportunities to minimize the costs and capitalize on the benefits.

We recognize that some communities in the Sierra Nevada differ from each other in important ways. Many communities are increasingly tied closely to metropolitan areas that may offer greater employment opportunities. But, there are other communities that are highly dependent upon traditional extractive industries. These distinctions suggest that individual communities will respond differently to the changes brought about by watershed restoration plans. This means that some communities may be able to adjust to the changes more rapidly than others.

All else equal, communities with transition plans and a better understanding of the watershed restoration program should get through the transition with higher levels of prosperity and lower levels of economic and social disruption. Individualized transition plans should be developed in conjunction with the watershed-specific restoration programs. For example, a transition plan might demonstrate ways for a community to take advantage of a restoration program to generate new jobs in watershed restoration suitable for workers displaced from the timber industry.

Table 6.1: Illustration of Potential Tools for Capturing Economic Benefits of Restoration to Pay for Restoration

Potential Ecological Change	Potential Manifestation of Economic Benefit	Potential Tools for Capturing the Benefit[2]
A. Cleaner water in streams	A.1 Lower costs for municipal-industrial water users	A.1 Charges added to water-utility rates
	A.2 Greater recreation value for rafters, anglers, et al.	A.2 Recreation permit for commercial outfitters or private recreationists
	A.3 Increased property values for properties with enhanced view of or access to cleaner streams	A.3 Additional property-tax collections from properties adjacent to cleaner streams
	A.4 Reductions in stream sediment mean less deposition of mud in stream channels, roadside ditches, reservoirs, etc., and lower dredging costs for landowners, reservoir owners, and governments	A.4 Contributions from property owners to a fund to finance restoration activities resulting in reduced sediment
	A.5 Reductions in stream sediment can reduce the wear and tear that grit imposes on dams, hydropower turbines, etc. and lower operating and maintenance costs for dam operators and other industrial water users	A.5 Contributions from dam owners and industrial water users to a fund to finance restoration activities resulting in reduced sediment
B. Reduced flood risk	B.1 Reduced costs for private and public landowners for flood insurance or from actual flooding	B.1 Expenditures by a flood-control district
	B.2 Increased property values for properties that enjoy less flood risk	B.2 Property-tax levy for properties experiencing less flood risk at lower cost than without restoration
	B.3 Reduced threat of erosion for properties adjacent to streams	B.3 Property-tax levy for a soil-water-conservation or flood-control district
C. Investment in restoration actions	C.1 More business opportunities in restoration-related industries	C. Allocation to restoration of a portion of local, general-fund revenues derived from restoration-related businesses

[2] These tools are presented for illustrative purposes. They are not recommendations. In application, these tools would be subject to state and local tax laws and other requirements.

Potential Ecological Change	Potential Manifestation of Economic Benefit	Potential Tools for Capturing the Benefit
D. Increased ecological health	D.1 Increased native fish populations and increased opportunities for recreational fishing	D.1 Surcharge for angling license
	D.2 Reduced costs for governmental agencies, landowners, and water users to cope with ecological crises	D.2 Allocation of funds from existing programs, such as CALFED, to pay for restoration in the Sierra Nevada
	D.3 Increased intrinsic value of Sierra Nevada watersheds	D.3 General tax levy, sale of conservation bonds, solicitation of private funds for restoration.
	D.4 Better environment for future generations	D.4 Sale of conservation bonds to be paid in the future
	D.5 A watershed with greater ecological health may be capable of supplying timber and livestock forage that is more valuable than what is available from a degraded ecosystem	D.5 Negotiated contracts for future logging and grazing rights, contingent on the restoration of ecological health in the watershed
	D.6 Maintain research opportunities so scientists can learn more about watersheds and restoration	D.6 General-fund support for basic research; negotiate contracts with firms to develop expertise and technologies that can be applied to restoration projects elsewhere
E. Enhanced natural-resource amenities	E.1 More households attracted to the area, more jobs, higher land values	E.1 Allocation of local tax revenues to support restoration activities that sustain natural-resource amenities
	E.2 Increased profits for land developers seeking to develop nearby parcels	E.2 Negotiated contracts with developers, e.g., to fund projects to restore the ecological function of riparian areas that also would create aesthetic benefits for neighboring lands
	E.3 Increased profits for owners of commercial recreational sites capitalizing on enhanced amenities	E.3 Negotiated contracts with owners, e.g., to fund projects to restore the ecological function of riparian areas that also would create aesthetic benefits for neighboring lands
F. Increased streamflows in late-summer months	F.1 Increased property values for properties adjacent to streams	F.1 Allocation to restoration of a portion of property-tax revenues derived from higher property values
	F.2 Increased water supplies for downstream users	F.2 Contributions from downstream water users to a fund to finance restoration activities resulting in higher stream flows

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APPENDIX A: WATERSHED IMPACTS OF MANAGEMENT ACTIVITIES

IMPACTS OF LIVESTOCK GRAZING

Soils. Elevated erosion and sedimentation are the most widespread water quality problems caused by land management in the Sierra Nevada (CWWR, 1996; USFS, 1999; USFS, 2000a). Studies repeatedly have shown that grazing significantly elevates surface and channel erosion and consequent sediment delivery to streams (Lusby 1970; Dunne and Leopold, 1978; Kauffman et al., 1984; Platts, 1991; Bauer and Burton, 1993; Fleischner, 1994; Rhodes et al., 1994, Belsky et al., 1999; Rhodes and Greene, *in process*). The increased surface erosion is caused by soil compaction effects operating in tandem with the denudation of vegetation and groundcover via trampling and browsing. Soil compaction and loss of soil productivity caused by grazing is significant in grazed areas of the Sierra Nevada, such as the west-side hardwoods ecosystem, where approximately 96% of the area is grazed (USFS 2000a, p. 3-235 and 3-236,).

Transect data from Sierra Nevada forests indicates that the amount of bare ground in grazed areas in sage steppe increased in recent decades on the Toiyabe and Stanislaus forests (CWWR 1996, p. I-118,). On all other forests, the recovery of bare ground in sage steppes was nominal (CWWR, 1996). These data indicate that current and recent grazing management approaches are still increasing erosion and topsoil loss caused by grazing in some areas, and impeding recovery in other areas.

Soil loss from elevated erosion creates a positive feedback loop for soil erosion, because it increases surface runoff, which further increases soil loss. Topsoil loss also reduces soil productivity, reducing the potential for and rate of revegetation and recovery.

Morphology. Currently, the USFS guidelines for the allowed amount of stream bank damage annually allows grazing to increase bank instability and channel erosion in some areas and retard recovery elsewhere. Current guidelines allow 20% bank disturbance per year (USFS 2001, p. 5.1-33). Most stream systems do not have the potential to recover annually from such levels of disturbance, especially in their currently degraded state. Even in systems that can recover annually from such levels of disturbance the allowed level of disturbance still reduces the amount of annual recovery and total recovery over a span of years.

Grazing also has contributed to significant gullying in meadows (USFS, 2001), greatly elevating stream channel sediment delivery. This also has significantly reduced the productivity of many grazed meadows (USFS, 2001). Existing gullying and channel incisement has not shown any signs of recovery in recent decades, despite efforts to reduce grazing impacts (USFS, 2001).

The impacts on riparian and meadow vegetation, soils, and hydrology have caused profound effects on stream channel conditions. Elevated bank erosion caused by bank instability, together with increased surface erosion has greatly elevated sedimentation. Although data are limited, available information indicates that this has contributed to the loss of pool volume and frequency and increased fine sediment levels. Both of these effects are highly deleterious to the production and survival of salmonids (Meehan, 1991; Rhodes et al., 1994). Relatively minor increases in fine sediment levels can cause significant reductions in salmonid survival.

Grazing reduces the availability of overhanging banks (Platts, 1991; Rhodes and Greene, *in process*), as thoroughly documented in meadows on the Inyo National Forest (Knapp and Matthews, 1996). Overhanging banks are an essential part of salmonid habitat because they provide shade, places for hiding from predators, resting places, and feeding (Matthews, 1996).

Vegetation. Livestock grazing also increases the spread of noxious weeds by simultaneously dispersing weeds and disturbing soils and native vegetation, which helps noxious weeds out-compete native species (J.B. Kauffman, Assoc. Prof. of Fisheries and Wildlife, OSU, *pers. comm*., 1997; Belsky et al., 1999; Belsky et al., 2000; USFS, 2001). Noxious weeds can increase both erosion and runoff (CWWR, 1996; USFS, 2001). Such infestations also can reduce soil productivity via nutrient and soil depletion. Currently, the worst noxious weed infestations in the Sierra Nevada occur in areas where the vast majority of the area is grazed (CWWR, 1996; USFS, 2001), such as the west-side hardwood ecosystems.

Grazing also appears to reverse vegetative recovery. Schulz and Leininger (1990) found that density of woody species was significantly less in riparian reaches where grazing had been re-introduced than within exclosures. Livestock grazing greatly increases fluvial channel erosion by decreasing bank stability via bank trampling, browsing, and the loss and depression of deep-rooted vegetation such as sedge and willows (Platts, 1991; Fleischner, 1994; Rhodes et al., 1994; Knapp and Matthews, 1996; Rhodes and Greene, *in process*). This is the general case in grazed areas in the Sierra Nevada (CWWR, 1996; USFS 1999; USFS, 2000a) and has been exceedingly well documented in specific cases, such as in meadows on the Inyo National Forest (Knapp and Matthews, 1996). The loss of bank stability greatly increases channel erosion and delivers sediment to channels with almost complete efficiency. Even limited livestock grazing damages banks (Kauffman et al., 1983; Marlow and Poganick, 1985). Kauffman et al. (1983) found that although relatively light grazing allowed some, albeit impeded, vegetative recovery, bank erosion in grazed areas was about three times higher than in comparable ungrazed reaches.

Studies repeatedly have found that grazing alters vegetation in many ways. Browsing reduces the height of plants. Trampling also reduces groundcover and vegetation composition. Stream incisement desiccates riparian areas causing a shift in plant communities towards more xeric (“dry”) assemblages, which has occurred in many damaged riparian areas and meadows in the Sierra Nevada (CWWR, 1996; USFS, 1999; USFS, 20001). Studies have shown that grazing stunts the recovery or causes losses of many hydric (“wet”) shrubs, hardwoods, and other deep-rooted species, such as sedge, in the Sierra Nevada (Knapp and Matthews, 1996; CWWR, 1996) and other areas (Schulz and Leininger, 1990; Platts, 1991; Greene, 1991; Green and Kauffman, 1995).

Flow Regimes. Grazing also contributes to increased runoff and reduced baseflows via effects on vegetation. Loss of groundcover can increase surface runoff. Grazing also aids in the dispersal and establishment of noxious weeds, infestations of which increase runoff (USFS, 2001).

These alterations of runoff regimes are serious due to their effects on downstream beneficial uses. Contributions to flooding increase property damage. Reductions in baseflows reduce flows during periods when they are most critical to the survival of aquatic and riparian dependent flora and fauna, as well as downstream water users.

Water Quality. Grazing reduces stream shading and suppresses its recovery through the elimination of and change in riparian vegetation. Stream shading is vital to the control of temperature extremes (McCullough, 1999). However, other grazing impacts compound the effects on water temperatures. In depositional areas, grazing effects tend to widen channels resulting in shallower flow depths (Platts, 1991). Magilligan and McDowell (1997) documented that grazed reaches were significantly wider than ungrazed adjacent stream reaches in exclosures. Wider and shallower flows undergo greater temperature extremes. The loss of baseflows and groundwater inflows, caused by channel incisement, also increase seasonal temperatures. Separately, and in concert, these factors increase summer water temperatures and reduce winter water temperatures. This is significant because increased summer water temperatures are one of the most widespread water quality problems on Forest Service lands in the Sierra Nevada (USFS, 1999; 2000a). Salmonids and amphibians both are sensitive to increases in seasonal water temperature extremes. Elevated water temperatures can cause direct mortality, reduce egg viability, and increase disease virulence in salmonids (McCullough, 1999). Elevated water temperatures also provide warm-water species with a competitive edge over salmonids (McCullough, 1999). Water temperature increases also reduce the usable habitat available to salmonids and some amphibians and act as an effective barrier between isolated populations.

Livestock grazing also is a significant source of fecal coliform and elevated nutrient pollution in streams and receiving lakes and reservoirs. Fecal coliform and related biota can pose health problems for humans consuming the water. Accelerated nutrient pollution contributes to increased eutrophication, especially in receiving lakes and reservoirs. Together with other livestock wastes in water, increased eutrophication can decrease oxygen concentrations in water bodies during key periods, stressing native aquatic life. Eutrophication increases algal blooms, reducing the clarity of water bodies.

Need for Passive Restoration: Benefits and Risks

The previous discussion demonstrates a very high need for passive restoration measures to ameliorate the effects of grazing on watershed condition and function. Studies repeatedly have demonstrated that the elimination or suspension of grazing has many significant benefits for aquatic resources (Kauffman, 1983; Schulz and Leininger, 1990; Green, 1991; Platts, 1991; Elmore, 1992; Fleischner, 1994; Rhodes et al., 1994; Henjum et al., 1994; Knapp and Matthews, 1996; Magilligan and McDowell, 1997; Belsky, 1999; Rhodes and Greene, *in process*).

There has been some nominal recovery in the amount of bare ground in grazed meadows over the last 40 years. Prior to 1956, bare ground in meadows on Sierra Nevada national forests averaged about 11%, while it now averages about 5%. While this is a positive outcome, it also indicates that recent grazing practices are allowing only very nominal recovery of ground cover in grazed meadows, on the order of about 1.5% year. Studies consistently have demonstrated that ungrazed areas undergo a far more rapid rate of recovery of vegetation and groundcover in riparian and meadow areas than in comparable grazed areas (Schulz and Leininger, 1990; Platts, 1991; Green, 1991; Rhodes et al., 1994; Henjum et al., 1994; Magilligan and McDonald, 1997; Belsky et al., 1999; Rhodes and Greene, *in process*). Knapp and Matthews (1996) documented that grazing significantly impeded the recovery of groundcover and other soil-stabilizing vegetation in meadows on the Inyo National Forest.

PASSIVE RESTORATION BENEFITS

Soils. It is expected that very significant recovery from soil compaction infiltration rates would occur within 9-18 years (Kauffman et al., *in process*). Therefore, with the cessation of grazing, reduced flooding and increased baseflows would occur within this same timeframe. However, full recovery of soil hydrologic properties may take 20-30 years.

Reductions in sediment delivery would not prevent on-going in-filling of storage reservoirs, but it would partially arrest accelerated sedimentation. This would extend reservoir life in comparison with current management practices.

Morphology. Although recovery of stream incisement and channel form likely will lag behind the recovery of vegetation (Kondolf, 1993; CWWR, 1996), it is likely that significant recovery would occur within 10 years and continue for at least a decade or so. Magilligan and McDowell (1997) found significant recovery of channel widths in exclosures greater than 20 years old, while Rhodes and Greene *(in process*) found highly significant differences between channel widths in considerably younger exclosures and grazed areas.

With the recovery of bank stability, there also should be an increase in overhanging banks on streams in low-gradient streams in floodplains. Knapp and Matthews (1996) found significantly more overhanging banks in ungrazed meadow reaches than in comparable grazed reaches on the Inyo National Forest. In forested rangelands in Oregon, Rhodes and Greene (*in process*) found similar results consistently across a wide variety of stream types and stream settings. Matthews (1996) documented that overhanging banks were critical to salmonids, as other assessments of salmonid habitat requirements also have concluded (e.g., Platts, 1991). Based on the findings of Rhodes and Greene (*in process*), significant recovery of overhanging banks likely will occur within 10 years of grazing cessation in most low-gradient, soft-banked streams in floodplains.

Vegetation. Elimination or suspension of grazing would allow fairly rapid recovery of groundcover in riparian areas, with somewhat slower recovery in uplands. Deep-rooted hydric plants, such as sedge and willow, would begin fairly rapid recovery in most areas with grazing cessation, accelerating bank stability recovery. Due to these factors, sediment delivery and sedimentation would measurably decrease in most grazed areas within five years after the cessation of grazing.

Although vegetation and stream shading may require 25-40 years for full recovery after the cessation of grazing (Rhodes et al., 1994), it will begin fairly rapidly in all but the most damaged sites. It can be expected that, due to the combined recovery of channel width and stream shading, there will be measurable decreases in water temperatures in most small streams within 10 years after the cessation of grazing.

Grazing cessation will not eliminate the spread of noxious weeds, especially in infested areas, due to other vectors for dispersal and establishment, such as road traffic. However, cessation of grazing will immediately begin to slow current rates of noxious weed spread. The recovery of soils and the elimination of browsing and trampling of native species will provide ancillary benefits to native plants in their competition with non-native noxious weeds. In a review of a large body of available literature on the effects of grazing on noxious weed spread and establishment, Belsky et al. (2000) concluded that livestock grazing was one of the major causes of noxious weed spread in the west and that there was a lack of evidence to support the proposition that grazing could be used to control the spread of noxious weeds. The CCWR Report (1996) came to similar conclusions regarding grazing and cheatgrass.

Flow Regimes. Due to the relatively slow nature of recovery in soil conditions and channel form, it is likely that the recovery of water tables and baseflows will be fairly slow. Nonetheless, case histories have demonstrated increased baseflow in streams within 15 years after the cessation of grazing (Ponce and Lindquist, 1990; Reeves et al., 1991). Winegar (1977; 1978, as cited in Reeves et al., 1991) found that fencing of a stream in eastern Oregon not only increased summer baseflows but also ceased the consistent freezing of the stream during winter. Restoration of riparian soils and vegetation via cessation of livestock damage is one of the most promising means for increasing summer baseflows (Ponce and Lindquist, 1990).

Water Quality. The recovery of water temperatures to natural ranges likely will increase the productivity and survival of salmonids in currently usable habitat and also increase the extent of usable habitat (Theurer et al., 1985; McCullough, 1999). Over longer timeframes, the recovery of water temperatures can restore the connectivity among currently isolated populations of fish (McCullough, 1999), which is critically needed to rebuild healthy salmonid populations (Henjum et al., 1994).

PASSIVE RESTORATION RISKS

From an aquatic perspective, the cessation of grazing as a passive restoration measure conveys no risks. Livestock grazing provides no benefits to the functions or conditions of watersheds or embedded aquatic resources. Therefore, there is a high degree of certainty that there is no risk to aquatic resources from the cessation of grazing. On streams of all types, the range management strategy that is the most compatible with the protection and restoration of aquatic resources is the “no livestock grazing” strategy, as researchers repeatedly have concluded (e.g., Platts et al., 1991; Elmore, 1992; Anderson et al., 1993; Rhodes et al., 1994; Henjum et al., 1994, USFS, 1997c).

Need for Active Restoration: Benefits and Risks

With very few exceptions, there is a very low need for active restoration of grazed areas, because passive restoration via grazing cessation repeatedly has been shown to be effective at restoring damaged resources, especially in riparian zones. The natural recovery of damaged resources can take considerable time for some conditions (e.g. soil compaction), and the rate also is limited by the degree of riparian damage. Natural recovery in uplands can be even slower, depending on the site conditions and level of damage. Active restoration measures can do little to increase the rate of recovery of vegetation, bank stability, channel form, stream shading, soil compaction, water table elevation, and in-channel thermal and sediment regimes.

Attempts to accelerate natural riparian recovery or merely treat the symptoms of degradation caused by livestock grazing can exacerbate existing problems and create additional problems. For instance, attempts to reduce bank erosion via bank hardening with riprap or rocks in meandering streams in floodplains can de-stabilize downstream reaches while also severely impeding channel recovery processes and the development of overhanging banks that are vital to salmonids. In some degraded streams, attempts to accelerate the recovery of channel complexity by adding wood or other structures can result in accelerated channel widening, preventing the recovery of the channel width/depth ratios and water temperatures needed for fish recovery (Kauffman et al., 1994; Kauffman et al., 1997).

Some active restoration efforts convey fairly low risks but provide limited benefits that are seldom cost-effective. For example, planting of desirable hydric plants, such as willows, often has very limited benefits in highly degraded sites due to very low survival rates of the plantings (Dr. J.B. Kauffman, Assoc. Prof. of Fish and Wildlife, OSU, *pers. comm.*, 1997). However, such plantings usually confer low risks of causing additional or worse damage, as long as native species, adapted to the site, are used. Planting of non-native vegetation can stunt the recovery of native riparian species suited to the site.

Attempts to reduce noxious weeds via hand pulling can have beneficial effects without incurring risks, although it may not be cost-effective in some cases. The use of herbicides is extremely risky due to water quality effects on shallow groundwater, streams, and aquatic biota. Herbicides also can severely thwart the recovery of native plant species. Mechanical treatments of noxious weeds cause significant soil damage with persistent erosional consequences that reduce soil productivity and contribute to aquatic resource degradation.

ROADS

Impacts of Roads

Soils/Morphology. Roads significantly increase erosion and sedimentation in streams via several mechanisms. Roads radically elevate on-site erosion and sediment delivery for the life of the road (Geppert et al., 1985; Potyondy, 1991; USFS et al., 1993; Rhodes et al., 1994). Elevated surface erosion from roads ranges from 50 to greater than 220 times natural levels during the construction phase (Potyondy et al., 1991; King, 1993; Rhodes et al., 1994). Although the rate of surface erosion declines over time, after construction it remains well over an order of magnitude higher than natural levels for the life of the road. Surface erosion from unpaved roads increases with increasing traffic (Reid and Dunne, 1984). Road reconstruction also significantly elevates erosion for several years, as well as reversing whatever recovery might have occurred prior to reconstruction.

Studies consistently indicate that roads increase the frequency of mass failures in mountainous terrain (Dunne and Leopold, 1978; Geppert et al., 1985; MacDonald and

Ritland, 1989; Rhodes et al., 1994). Mass failure volumes from roads are orders of magnitude greater than from undisturbed areas on a per unit area basis (Dunne and Leopold, 1978; Geppert et al., 1985; Rhodes et al., 1994). It appears that roads increase mass failure rates over an area of influence that is far wider than the roads themselves (Larsen and Parks, 1997).

The elevated erosion from road surfaces, cuts, and fills cause severe and long-lasting losses of topsoil and soil productivity in watersheds (USFS, 1999). The combined effects of compaction, road maintenance, and traffic effectively “zero out” soil productivity for the life of a road and several years more after roads are abandoned.

Road crossings cause extreme increases in sediment delivery to streams. Fowler et al. (1987) documented that road crossings increase turbidity by more than 50 times ambient levels. Road ditches and gullying from midslope culverts and other road drainage features increase the extent of the area of roads directly contributing sediment delivery and increased runoff to streams, far beyond that caused by road crossings alone (USFS, 1999). During storms, road crossings frequently clog and/or fail to pass flows due to inadequate design capacity, resulting in road blowouts that can add vast quantities of sediment directly to streams. During such events it is not uncommon for such blowouts to trigger other road blowouts downstream due to clogging of culverts by debris and sediment from upstream events.

The combined effects of logging and roads also increase sediment delivery via accelerated stream channel erosion and headward extension (Megahan and Bohn, 1989; Heede, 1991), even when riparian vegetation is retained. MacDonald and Ritland (1989) concluded that roads typically double suspended sediment yield, notwithstanding state of the art construction and erosion control. Even in the absence of mass failures, suspended sediment contributions from surface erosion on roads typically are in the range of 5 to 20 percent above background and remain at elevated levels for as long as roads are in use (Ibid.).

Although surfaced roads tend to have lower rates of surface erosion from the travelway, they trigger vast and long-lived increases in surface runoff that greatly accelerate surface erosion on fills, ditches, and downslope areas (USFS, 1999; Jones et al., 2000). Most of this eroded sediment is delivered to streams (USFS, 1999). The increased runoff contributes to increased mass failure rates. Surfaced arterial roads also tend to be in close proximity to streams, greatly increasing the efficiency of sediment delivery. Surfaced roads also tend to be wider (USFS, 2001), increasing the impacts per unit length.

Due to their effects on erosion and sediment delivery, roads are a major cause of loss of storage in downstream reservoirs. This reduces the ability of the reservoirs to provide flood control, water supply, and electricity, especially during droughts.

Hydrology. Roads also severely disrupt hydrology via several mechanisms. Roadcuts intercept subsurface flows (Megahan, 1972; Jones et al., 2000). Roadcuts inexorably intercept subsurface flows when they cross hillslopes that carry subsurface flows to streams (Kirkby, 1978). Roads act as extensions of the channel network because they route overland flow from roads to streams via drainage ditches and gullying from midslope culverts (Jones et al., 2000). This effectively increases drainage density, which contributes to peakflow elevation (i.e., flooding). Roads radically elevate surface runoff, even during minor snowmelt or rain events, due to their combined effects on soil compaction and infiltration. Roads also increase snow accumulation and melt rates via forest canopy removal. These combined mechanisms from roads are probably the reason that roads increase peakflows, as documented in many studies (King and Tennyson 1984; King, 1989; MacDonald and Ritland, 1989; USFS et al., 1993; Rhodes and Purser, 1998). It is likely that these increased flows contribute to increased downstream flooding. The increases in peakflows caused by roads appear to be most pronounced and consistent in systems dominated by snowmelt (MacDonald and Ritland, 1989; Rhodes et al., 1994; Rhodes and Purser, 1998), as are Sierra Nevada watersheds. It also is likely that the hydrologic effects of roads are not ameliorated by time unless roads are abandoned or obliterated.

Roads within floodplains sever streams from floodplains and wetlands, effectively reducing floodplain storage of floodwaters. This exacerbates the other effects of roads on floods.

Roads adversely affect baseflows. The interception of subsurface flow likely will reduce downstream water table elevations. Surface runoff from roads, together with road drainage to streams, effectively prevents significant quantities of water from percolating into the soil and then into local groundwater systems that provide baseflows (USFS, 1999). Compaction and soil loss from roads both reduce the amount of water storage in soils for baseflow maintenance. These combined road effects contribute to reductions in baseflows.

Roads within riparian zones rob streams of shading and the recruitment of large woody debris (LWD) needed for stream complexity and prevent their recovery for the life of the road (USFS et al., 1993; Rhodes et al., 1994). Since trees also are removed along roads to reduce hazards to the roads, roads within riparian areas also impede LWD recruitment and shading in this manner.

Roads located in floodplains, riparian areas, or otherwise in close proximity to streams also have significant negative effects on streams, that are somewhat indirect. Arterial and collector roads in such locations often are untenable, yet land managers attempt to maintain the roads in their current position.[1] These attempts often have long-term negative effects on streams and aquatic habitats. The most common attempt is bank hardening by installing riprap or other materials that prevent stream channel recovery (e.g., the re-establishment of meander patterns and overhanging banks). Bank hardening often destabilizes downstream reaches through increasing bank instability and channel erosion.

Biota. Roads are a major agent of noxious weed dispersal and establishment (CWWR, 1996; USFS, 1999; USFS, 2001). The disturbed and eroding soils on fills, cuts, and ditches are conducive to noxious weed establishment.

Because they provide easy travelways for livestock, roads increase the extent and intensity of grazing damage. Roads provide livestock greater access to forested riparian areas, especially at stream crossings.

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[1] These attempts usually are futile. There are few locations (e.g., lava flows on active volcanoes, sand beaches) where human infrastructure is more transient than in floodplains and on streambanks. It is always only a matter of time before the structure is washed out.

The above combined effects of roads significantly degrade aquatic habitats. The elevated erosion increases sedimentation and turbidity. Elevated sedimentation increases fine sediment levels and channel width, while reducing pool volumes and channel complexity. Decreases in LWD also contribute to loss of pools and channel complexity. Shade loss, summer surface runoff, and reductions in baseflows exacerbate seasonal temperature extremes. Singly, and, in concert, these road effects significantly reduce the survival and production of salmonids, amphibians, and other aquatic- and riparian-dependent species.

Need for Passive Restoration

There is an extremely high need for passive restoration for roads. Due to the intensity, magnitude, longevity, and widespread nature of road effects, it is highly unlikely that aquatic resources in the Sierra can be recovered in the absence of passive restoration. Recovery on roads is exceedingly slow, even with relatively expensive road obliteration and decommissioning efforts. Further, these efforts often do little to reverse some impacts, such as subsurface flow interception. Even “temporary roads” that will be subsequently obliterated have long-term negative effects that always significantly outpace mitigation and rehabilitation measures. Further, on-going road construction, reconstruction, and use of roads not only increases the extent and intensity of watershed and aquatic resource damage, it adds to an already insurmountable backlog of needed road maintenance and active restoration needs.

Credible scientific recovery plans for aquatic resources consistently have stressed the need for a moratorium on road construction until, at least, widespread recovery has been documented (Henjum et al., 1994; Rhodes et al., 1994; ISG, 1996; Espinosa et al., 1997). Although there is an extremely high need for active restoration, such efforts will have very limited cumulative success unless and until comprehensive passive restoration for roads in critical aquatic habitats is realized. This passive restoration should include closing and abandoning large segments of the road network, reducing road traffic on remaining roads, and a complete moratoria on the construction and reconstruction of all roads in riparian areas and identified aquatic refugia, with very limited human health and safety exceptions.

Need for Passive Restoration: Benefits and Risks

Eliminating road construction, most reconstruction, and reducing road traffic while simultaneously closing and abandoning roads will have many significant ecological and economic benefits. Due to the persistent nature of on- and off-site road impacts, recovery will be slow, but at least initiated. Absent passive restoration of roads, recovery will never begin. Although passive restoration efforts will not reduce on-going impacts from existing road networks, they will prevent increases in the intensity and extent of effects. This will prevent elevation of existing levels of habitat degradation, downstream flooding, reduced baseflows, and loss of downstream reservoir storage from sedimentation.

There is a very high degree of certainty that the foregoing benefits would be realized, based on available data. However, many on-going risks and impacts will not be reduced without active restoration. For instance, roads in unstable terrain remain a risk, even under passive restoration. The failure to aggressively implement adequate passive restoration efforts will undermine all efforts to reduce the adverse effects of roads on watersheds and embedded physical and biotic resources.

PASSIVE RESTORATION BENEFITS

Soil/Geomorphology. Cessation of road construction and most reconstruction ensures that erosion and sedimentation is not increased.

Closure and abandonment of road segments would eliminate erosion and sediment delivery caused by road traffic. This would be a non-trivial benefit. Road traffic causes several-fold increases in erosion and sediment transport levels. It also would allow the process of recovery from soil compaction to begin. Although this process likely will be slow, it would contribute to reducing surface runoff and peakflow contributions and aid in the recovery of soil productivity.

Hydrology. Cessation of road construction also ensures no additional disruption of subsurface flows or increased contributions to elevated peakflows and downstream flooding. It also promotes retention of stream shade and LWD recruitment to streams as road construction typically occurs in riparian areas and along streams.

Vegetation. Although vegetative recovery would be slow on road prisms, especially travel surfaces, the cessation of use would allow the recovery of groundcover to begin (which would never occur while roads are in use). A limit on road construction would limit noxious weed dispersal establishment to existing roads. This would help prevent the incursion of weed dispersal via roads into currently unroaded areas. A moratorium on road construction and most reconstruction also prevents additional losses of forest productivity via compaction and topsoil loss.

PASSIVE RESTORATION RISKS

From an aquatic perspective, the cessation of road construction and reconstruction conveys absolutely no risks. For example, it is well documented that aquatic resources in unroaded areas are in far better condition than in comparable roaded areas, even when the unroaded areas have undergone severe disturbance such as intense wildfire (McIntosh et al., 1995; Huntington, 1995). Roads provide absolutely no direct or indirect ecological benefits to watersheds or aquatic systems. There is a very high degree of certainty that there is no risk to aquatic resources from the cessation of road construction and reconstruction.

There also is absolutely no ecological risk of closing significant portions of the road network to vehicular traffic. Vehicular traffic has no ecological benefits to aquatic resources. There is a very high degree of certainty that there are no risks from reductions in vehicular traffic.

There are some risks from road closure and abandonment, over the long term, unless there follows a nominal degree of active restoration. These risks include increased surface erosion from the road prism and ditches in the absence of road maintenance. Another risk is stream crossing failures as undersized and poorly designed culverts and crossings plug with debris or fail to pass flows from larger events. However, this risk already exists and generally is not increased by closure and abandonment in cases where such culverts *might eventually* be replaced. Even then, such failures may not be more severe than the accrued interim impacts from the use of an open road. Further, this problem can be easily remedied, via active restoration, by pulling stream crossings. Increased surface erosion from the road prism also can be largely reduced through active restoration via road re-contouring and obliteration.

The risk of elevated surface erosion is of medium uncertainty because it is likely that, in many cases, the reductions in erosion (due to road closures and ensuing passive recovery) will more than offset the potential minor increases in surface erosion on prisms and ditches. There also is a high degree of uncertainty that abandoning roads with poorly designed crossings will cause crossing failures at a greater rate that on open roads, such that cumulative sediment delivery over the long term is greater for the abandoned road than for a closed road. Again, the risk of culvert failure already exists on open roads and is unlikely to be significantly reduced in the near term under current management and budget levels. Road closure and abandonment does not increase the risk in the short term. As will be discussed in the section on active restoration, stream crossings should always be pulled as part of road abandonment.

Need for Active Restoration: Benefits and Risks

Due to the persistent nature and magnitude of road impacts (even under passive restoration) there is a very high need for active restoration on roads. This is necessary to reduce some of the long-term risks associated with passive restoration. Aquatic restoration plans consistently have stressed the need to reduce road impacts and the extent of road networks via road obliteration, relocation, and improved maintenance (e.g., Anderson et al. 1993; Rhodes et al., 1994). Even management plans aimed at perpetuating resource extraction in systems degraded by such activities have conceded the need to reduce road impacts via active restoration in order to lessen the aggregate damage from existing conditions and continued resource extraction (e.g., USFS et al., 1993; USFS and USBLM, 1995; USFS, 1999).

The primary active restoration needs are as follows:

1) Road decommissioning (permanent closure and abandonment, with all crossings pulled from streams and floodplains).
2) Road obliteration (decommissioning, plus de-compaction of the road prism and re-contouring of cut and fill slopes approximate to original slope condition).
3) Increased road maintenance on roads remaining open, including:
    - replacing all stream crossings that block fish passage and/or are inadequate to pass at least the flow and associated sediment load from a 100-year event;
    - rocking or graveling native-surface roads; and
    - improving road drainage, including rerouting road runoff away from streams and stream crossings.
4) Relocation of roads along streams that cannot be decommissioned.

Both decommissioning and road obliteration reduce the backlog of needed road maintenance. They also save road maintenance cost over time. This is especially true for roads that cross or are near streams that might fail during flood events. In these cases, obliteration and decommissioning save interim maintenance costs and the costs of rebuilding roads and crossings that will be periodically damaged, regardless of maintenance effort.

The magnitude of the physical benefits will be largely dependent on three factors. First, it will depend on whether the most damaging roads are targeted for such treatment. Generally, the most damaging roads are those that are the most heavily used, closest to streams, and/or in failure-prone areas. Most current management schemes prioritize roads for closure based on the level of current use and perceived needs for future forest reconfiguration or resource extraction, rather than the amount of damage the roads are causing (e.g., USFS and USBLM, 1995; USFS, 2000a). If such an approach continues to be followed, the effectiveness and efficiency of obliteration and decommissioning will be significantly undermined. The more that damaging roads are targeted for treatment, the more effective the treatments will be. In some watersheds, it is likely that some aquatic resource conditions will not improve, even with considerable treatment efforts, unless the most damaging roads are targeted for treatment.

Second, the degree of active restoration benefits is contingent on the magnitude of the treatment effort. Simply enough, the magnitude of the benefits will increase with increasing treatment levels.

Third, benefits also depend on the degree of implementation. While properly implemented road obliteration generally has considerable on- and off-site benefits, poor execution can limit or negate benefits. In some all-too-common cases, poorly executed road obliteration increases erosion and sedimentation problems. For instance, native roads (i.e., without gravel, pavement, or some other type of cover) commonly are partially obliterated by disking or ripping the roads in a direction parallel to the road, even in areas where road segments are parallel to the slope. This causes topographic concentration of runoff resulting in erosion of topsoil that exceeds surface erosion from unripped roads. It also significantly sets back vegetative recovery due to topsoil loss. Therefore, proper execution of restorative treatments is critical.

With these caveats, it is likely that an aggressive obliteration and decommissioning program would have considerable benefits. Over time, it should result in reduced downstream flooding, reservoir sedimentation, and levels of fine sediment in streams. It also should increase channel complexity, pool volumes, and channel widths in depositional environments. Provided roads near streams are targeted, some recovery of shade and water temperatures also should occur within 20 years. Most of these effects would improve salmonid survival and production and habitat conditions for amphibians.

ACTIVE RESTORATION BENEFITS

Soils/Geomorphology. Road decommissioning on abandoned roads immediately reduces the risk of crossing failures during large storms and events with high debris loads.

Road obliteration likely will reduce compaction, surface runoff, surface erosion, and sediment delivery, provided it is implemented carefully and correctly. These benefits are likely to accrue within a year of obliteration, although obliteration may initially increase surface erosion for one to two years (Potyondy et al., 1991). Post-obliteration, surface runoff and erosion should continue to abate for 5-15 years, until approximating natural background levels (Potyondy et al., 1991). Obliteration also will generally increase infiltration, especially on the travelway, reducing surface runoff and increasing percolation to the soil and local water tables. Obliteration also will significantly reduce the risk of mass failure and road damage within a few years of completion (Harr and Nichols, 1993).

Replacement of stream crossings immediately would reduce the risk of sedimentation from road crossing failure. This benefit would be realized in the next storm event of sufficient size to clog or overtop existing culverts.

Rocking or graveling of native surfaced roads would provide immediate, albeit somewhat transient and minor, reductions in erosion and sediment delivery from road travelways. However, roads so treated will still continue to deliver sediment at levels that are more than an order of magnitude above natural rates.

Relocation of damaging roads (including major arterials) that will remain open near streams, in floodplains, or on unstable slopes also would provide several significant benefits. First, it would help to reconnect streams to floodplains where connections have been severed by road prisms. Second, where roads impinge on the meander belt in the floodplain it would allow the streams to recover via migration and meander re-establishment. This also may aid in the re-establishment of overhanging banks critical to salmonids. Third, it would provide some reductions in direct flow and sediment contributions from road prisms. This can be significant in mountainous areas where arterial roads in close proximity to streams are sanded in the winter, delivering a large quantity of the sand to streams.

Improvement of road drainage could provide benefits within a year of execution. In some cases, road drainage improvement would require significant reconfiguration of road prisms, such as converting in-sloped roads to outsloped roads and significantly increasing the frequency of midslope drainage features such as culverts. Improved road drainage can provide some reductions in the frequency of mass failure on roads in some areas. However, this benefit is negligible in failure-prone areas.

Hydrology. Road obliteration also will reduce subsurface flow interception at road cuts. However, very little data have been collected on this issue. Subsurface flow dynamics may not appreciably recover on altered slopes over the course of a decade even with complete road obliteration.

If properly executed, road drainage improvement could provide minor reductions in contributions to peakflows, downstream flooding, and sediment delivery.

If roads are relocated far enough from streams, it would allow some recovery of stream shading, LWD recruitment, and bank stability from vegetation regrowth. This also may allow the removal of bank hardening treatments designed to prevent road washout. Additionally, road relocation would reduce maintenance and reconstruction costs incurred by periodic road damage from flooding.

These changes will provide incremental reductions in stream sedimentation, turbidity, and contributions to downstream flooding. Increased soil percolation also will increase downslope watertable elevations and baseflows.

Vegetation. Obliteration will aid in vegetative recovery on the road prism. Groundcover should begin to recover fairly quickly. While trees also may begin to colonize obliterated road prisms, full recovery of stands, including hydrologic functions and LWD recruitment likely will require more than 100 years.

Vegetative recovery in combination with the elimination of vehicular traffic will not eliminate the spread of noxious weeds on obliterated roads. However, these effects should greatly reduce spread rates and will increase the effectiveness of weed control efforts.

Biota. In aggregate, the above benefits would improve aquatic species' habitat conditions and reduce downstream flooding and sedimentation. Where crossings had blocked fish passage, improved fish passage would occur immediately after decommissioning, increasing population connectivity as well as increasing the potential for re-colonization. The benefits of removal of fish passage barriers would be immediate. However, some time may be required before populations are re-connected or previously blocked habitats are re-colonized.

ACTIVE RESTORATION RISKS

Active restoration of roads does incur some risks. Road obliteration and decommissioning can increase surface erosion and sediment delivery during initial operations and up to a year thereafter, before revegetation and reduced runoff benefits begin to accrue. That this may outweigh benefits during the one-year period is of medium certainty. Therefore, considerable care must be taken, especially with roads in close proximity to streams. For roads with a high risk of mass failure, it is of medium certainty that the benefits more than outweigh the risks.

Road obliteration also elevates the short-term risk of noxious weed spread on obliterated surfaces, because it causes lineal disturbance. Seeding with native vegetation together with periodic manual treatment of noxious weeds can reduce this risk that is of medium to low uncertainty, depending on proximity to infested sites.

LOGGING[2]

Impacts of Logging

Soils/Geomorphology. Gullying and headward channel erosion in small, low order ephemeral channels caused by logging can be a significant source of elevated sediment delivery. Megahan and Bohn (1989) found that channel expansion and headward erosion was a significant source of sediment delivery caused by logging and road construction in their study of granitic material in mountainous terrain with snowmelt-dominated hydrology in Idaho. Similarly, in a snowmelt-dominated site in Arizona, Heede (1991) documented elevated channel erosion, sediment delivery, and channel expansion caused by increased

[2] In this report, logging is defined as the anthropogenic removal of live and dead trees, regardless of the purpose. Therefore, logging includes both thinning and all mechanical fuel treatments. Notably, the estimates of logged area provided above do not include the area affected by thinning and fuel treatments. Therefore, the estimates of area logged are a minimum.

runoff from logging. Notably, both studies included retention of trees in buffers along the streams. Soil compaction from logging has caused gullying in areas of the Sierra Nevada (USFS, 2001). Logging also greatly elevates erosion and sediment delivery via its synergism with roads.

Logging significantly reduces soil productivity by increasing soil compaction and erosion while reducing the amount of downed wood (USFS, 1997b). Reduced soil productivity stunts revegetation. These effects also contribute to increased surface runoff. USFS (2001) noted that soil damage has already slowed tree growth in areas affected by logging.

Hydrology. Most logging has involved, and continues to involve, road construction, reconstruction, and elevated haul traffic. All of these activities greatly increase peakflow and sediment delivery to streams.

Logging consistently has been documented to increase runoff in areas where runoff is dominated by snowmelt (MacDonald and Ritland, 1989; Rhodes and Purser, 1998). These increases have been documented in both watershed and plot-scale studies (Rhodes and Purser, 1998). The primary mechanisms appear to be increased soil compaction, reduced infiltration rates, increased snow accumulation and melt rates, and reduced transpiration. The increased runoff primarily occurs during peakflow events (Rhodes and Purser, 1998). Therefore, it is likely that logging contributes significantly to increased downstream flooding and flood-related damage in these areas.

Plot scale studies indicate that 40 years are required after logging to return to nearly natural levels of runoff during rain-on-snow events (Coffin and Harr, 1992). Based on this data, it is highly probable that at least 726,448 acres, or roughly 6.4%, of the total area of the Sierra Nevada that has been logged since 1960 is contributing to increased downstream flooding and peakflow events.

Logging within riparian areas also reduces stream shade, causing increased summer water temperatures. The loss of shading typically requires 25-50 years for full recovery (Rhodes et al., 1994). Logging within about half a tree height of streams also reduces bank stability provided by vegetation. The loss of bank stability increases channel erosion and typically results in the loss of overhanging banks. Logging within a few tree heights of streams also elevates water temperatures by increasing air temperatures and other microclimatic effects (USFS et al., 1993).

Biota. Logging within riparian areas has a variety of persistent negative effects on aquatic resources. Logging within one tree height of channels reduces the rate of large woody debris (LWD) recruitment and the size of the LWD recruited. This effect persists for over 200 years after logging, provided regeneration is not severely hampered by reductions in soil productivity from logging (Rhodes et al., 1994). Because logging also reduces the size and amount of terrestrial LWD, it also reduces the ability of riparian areas to detain sediment from upland sources, such as roads.

Riparian logging also significantly increases damage to riparian vegetation and streams by facilitating livestock access to previously forested riparian areas and streams. In grazed areas, this is a non-trivial effect. As previously discussed, livestock grazing profoundly degrades riparian soils, vegetation, and stream channel attributes.

Vegetation. Logging accelerates the spread of noxious weeds. Logging machinery and log hauling spread weed seeds. Logging disturbance aids in weed establishment. This is especially the case for mechanical fuel treatments as they are extensive and involve contiguous disturbance. Noxious weed infestations reduce soil productivity and biodiversity, while increasing erosion and surface runoff (USFS, 2001).

Need for Passive Restoration: Benefits and Risks

There is an extremely high need for passive restoration for logging, for several reasons. First, logging is inextricably intertwined with the construction, reconstruction, and use of roads, all of which cause persistent and intense degradation. It is unlikely that recovery of degraded aquatic resources can occur without significantly reducing both road impacts and the extent of the road network. It is equally unlikely that this can be accomplished without greatly reducing or eliminating logging in key aquatic refugia, riparian areas, on steep/unstable slopes, and in other areas where logging will significantly impact watershed function.

Second, logging damage is extensive and persistent and not particularly treatable by active restoration measures. Third, current and proposed management for national forest lands not only is inadequate to prevent logging-related damage but will increase it.

PASSIVE RESTORATION BENEFITS

Targeted reductions in logging would have several significant environmental and economic benefits. It would remove a significant impediment to a cessation of road construction, most reconstruction, and reductions in the extent of the road network. This effect, alone, provides major benefits to aquatic resources, due to the intensity and longevity of road impacts.

Cessation of logging also would ensure that this activity's adverse cumulative effects on soils, forests, fuel loads and fire risk, sediment and runoff regimes, and stream channels will not increase. A targeted reduction in logging will insure no further damage occurs and allow critical areas time to recover from past damage (e.g., refugia and riparian areas, watersheds with critical habitats for at-risk aquatic species, roadless areas, watersheds with degraded stream conditions and/or with already high levels of logging, and other aquatic emphasis areas).

Cessation of logging also would help to reduce the current velocity of noxious weed spread. This would increase the effectiveness per unit of existing efforts to treat noxious weeds.

There is a very high degree of certainty that these benefits would accrue from elimination of logging in riparian and other critical areas.

PASSIVE RESTORATION RISKS

From an aquatic perspective, the cessation of logging in critical aquatic diversity and riparian areas conveys only a minor and unlikely risk: the potential for increased frequency and intensity of fire, absent thinning and other approaches to reduce fuel loads. However, this remains a matter of conjecture as there is no evidence that fire frequency or intensity has increased in the Sierra Nevada (CWWR, 1996). Further, there is no good field evidence from applicable case histories that thinning or other mechanical approaches can reduce the frequency and intensity of fire. Similarly, there is no good evidence that the potential benefits of such treatments might outweigh their adverse and long-lived cumulative effects on aquatic resources. In fact, the preponderance of available data and information indicate that logging to reduce fuel and fires will have ecological costs well in excess of potential benefits.[3] Finally, the CWWR Report concluded that funds for fuel reduction via logging would more effective if diverted to prescribed fire treatments.

Need For Active Restoration: Benefits and Risks

There is a low need for active restoration for logging-related damage. The effects of logging are not particularly amenable to active restoration. Although recovery from many impacts will be slow, active restoration can do little to accelerate the recovery. For instance, the loss of terrestrial and in-channel LWD levels can only be recovered via the re-growth of forest vegetation and recovery of forest structure. Full recovery of the necessary rate, size, and types of LWD recruitment probably will require more than a century. Little can be done to accelerate this process without incurring additional risks of setting back recovery or causing additional problems. For instance, treating competing vegetation via tilling or herbicides likely will increase erosion by reducing groundcover or disturbing soils. Treatment of competing vegetation also may reduce soil productivity by eliminating nitrogen-fixing vegetation.

In aggregate, the benefits of active restoration for logging are likely to be limited. This is of medium certainty. Active restoration efforts that do not involve additional soil disturbance or herbicides are likely to incur limited risk with medium certainty.

DAMS AND DIVERSIONS

Impacts of Dams and Diversions

Soils/Geomorphology. Dams radically alter sediment transport-regimes. Dams, especially those with larger reservoirs, trap almost all sediment that is normally transported downstream by the river. This has several negative effects on streams. First, water released from the dams without sediment causes significant channel erosion for miles below the dams. Some call this phenomenon "hungry water." This typically results in channel incisement[4] and widening.

[3] Fire has played an important role in the development of Sierra aquatic-riparian systems (USFS, 2000a). There is plentiful evidence of resilience of native fishes in the face of fire impacts, even intense burns (Beschta et al., 1995). Additionally, comparisons of certain known harmful effects of logging against effects of wildfire (which can be neutral or even beneficial to aquatic systems) suggest that tactical logging intended to reduce fire risk poses more risk to aquatic and riparian ecosystems than the fire itself (Beschta et al. 1995; Erman, 1996; Rieman and Clayton 1997).

[4] Channel incisement is the "downcutting" of a stream channel, resulting from natural and unnatural processes. A downcut stream is the mark of a degraded stream.

Even relatively minor incisement can significantly alter groundwater interactions with streamflow.

Second, the “hungry water” usually entrains all finer sediments and transports them downstream toward the ocean. This results in a significant coarsening of substrate. Over time, this can result in a complete loss of gravel suitable for salmonid spawning. Kondolf (1997) noted that gravel was "being artificially added to enhance available spawning gravel supply on at lest 13 rivers in California as of 1992 (cite omitted). The largest of these efforts is on the Upper Sacramento River, where from 1979-2000 over US$22 million will have been spent importing gravel." However, this had highly transient benefits, because the added gravels were washed away within years due to the on-going effects of dams and “hungry water.” Because the volume of sediment that can be tractably added to spawning reaches is minor in comparison to the amount lost due to the effects of reservoirs, gravel additions have little promise for offsetting the effects of dams on substrate and salmonids.

The loss of sediment supply due to reservoir entrapment eventually reduces sediment supply to beaches. This results in the loss of coastal sand, increasing shore erosion (Kondolf, 1997), and necessitates the mining of sand from rivers that then is hauled and dumped on beaches.

Hydrology. By design, dams and diversions significantly alter and redirect the flows of the river. The alterations in flows typically alter water temperature regimes as well. These flow-mediated changes in water temperature strongly affect salmonids, other cold-water fish, and stream-dwelling amphibians such as the foothill yellow-legged frog.

Reduced flows decrease the amount of usable spawning and rearing habitat. They also concentrate aquatic predators and prey in pools and other restricted areas, resulting in food-chain imbalances.

Biota. Flow alteration can have very direct effects on in-stream biota. Releases from the reservoirs during the incubation period for salmonids and amphibians can scour eggs, resulting in high levels of mortality. A lack of releases during salmonid incubation can dewater the channels, stranding redds and resulting in high levels of mortality.

Reservoirs also negatively affect salmonids by blocking fish passage and severing the connectivity among habitats and populations. By converting riverine habitats to slackwater habitats, reservoirs also eliminate habitats for other riverine species.

Need for Passive Restoration: Benefits and Risks

There is an extremely high need for passive restoration for dams and diversions. Within the context of this topic, passive restoration for dams and diversions includes: cessation of construction of additional dams and diversions and the reduction or elimination of water stored in reservoirs or diverted out of stream. Passive restoration would ensure that additional impacts do not accrue. Reductions in water storage could aid in restoring flows toward more natural levels, which likely will restore some channel functions.

Cessation of construction of additional dams and diversions conveys no additional risk to aquatic resources; this is of very high certainty. Reducing or eliminating diversions and storage also conveys very limited risks to aquatic resources.

ACTIVE RESTORATION BENEFITS

There is a very high need for active restoration for dams and diversions, such as reconfiguration to reduce sediment storage behind dams, altered operations to better mimic historic downstream flow regimes, and decommissioning and removal of some dams and reservoirs.

Soils/Geomorphology. There are several possible methods to provide bypass of sediment downstream through or by reservoirs. These can aid in improving downstream substrate conditions, reducing channel incisement, and reducing the loss of beaches. These methods do convey risks. Unless properly designed they can severely degrade substrate conditions. The release of high levels of suspended sediment concentrations during low flows also can cause fish kills. Both of these risks are of medium certainty, especially if sediment bypass systems are not carefully designed.

Hydrology. Reservoir operations also can be altered to better mimic historic flow regimes on rivers. This likely will aid in thermal regulation while reducing the frequency of direct mortality caused by channel dewatering or scour during incubation periods. Although improved flow regimes may aid in the recovery of channel complexity, improved substrate conditions and recovery from incisement is unlikely to occur without successful efforts to partially restore sediment transport regimes.

Biota. The decommissioning and removal of dams would have several benefits. Slackwater habitat would be reclaimed as riverine habitat, although full ecological recovery of previously inundated areas would be slow. It also would reconnect riverine habitats and biotic populations and improve passage for terrestrial species through riparian corridors. Over the long term, dam removal also would be extremely effective for restoring flow regimes and sediment regimes, although the latter would clearly require a period of adjustments due to the amount of sediment stored in reservoirs. Restoration of the sediment supply would benefit channel form, channel substrate, and beach and shoreline dynamics, all of which are important habitat elements for aquatic and riparian biota.

ACTIVE RESTORATION RISKS

Dam removal would convey some significant risks, especially from the release of sediments stored in reservoirs. It is possible that some engineering solutions can be employed to slowly release the sediments in a way that minimizes harm to downstream resources, but that is of medium certainty.