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Riparian and Watershed Management in the Interior Northwest: An Interdisplinary Perspective

Proceedings of a symposium
held at Eastern Oregon State University
La Grande, Oregon
September 10–12, 1998

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Proceedings of a symposium held at Eastern Oregon State University La Grande, Oregon September 10–12, 1998

Compiled by:
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Table of Contents

Riparian and Watershed Management—Where Science and Policy Should Meet 1
THOMAS M. QUIGLEY, Program Manager, Managing Natural Disturbances to Sustain Forest Health Program, Pacific Northwest Research Station, USDA Forest Service

Allowing Watersheds to Function—A Riparian/Aquatic Perspective 2
ROBERT L. BESCHTA, Department of Forest Engineering, Oregon State University

The Myth of Range/Watershed Health 6
E. LAMAR SMITH, Rangeland and Forest Resources, University of Arizona, Tucson, AZ

Using Proper Functioning Condition Analysis to Promote Collaborative Watershed Management. 12
JOHN W. ANDERSON, Fishery Biologist, Wallowa-Whitman National Forest

How Human Values, Filters, and Perspectives Affect Riparian Management 13
LORI A. CRAMER, Department of Sociology, Oregon State University, Corvallis, OR

Calling All Experts: Using Science in Watershed Policy and Decision Making 18
PAUL W. ADAMS, Professor and Forest Watershed Extension Specialist, Forest Engineering Department, Oregon State University, Corvallis

An Environmental History of Riparian Areas in Southeast Oregon 19
NANCY LANGSTON, Department of Forest Ecology and Management and Institute for Environmental Studies, University of Wisconsin, Madison, WI

Ecosystem Health for the Forests of Eastern Oregon 25
PETER GREEN, Natural Resources Advisor, Governor's Office, Salem, OR

Policy and Management Lessons Learned: 25 Years of the Oregon Forest Practices Act 27
TED LORENSEN, Oregon Department of Forestry, Salem, OR

Responses of Selected Central Oregon Streams to Changes in Grazing Management 31
MICHAEL M. BORMAN, Department of Rangeland Resources, Oregon State University, Corvallis, OR and CHRISTINE R. MASSINGILL, Mainstream Contracting, Alamogordo, NM

Reasonable Management Changes to Improve Water Quality and Quantity 38
J. RONALD MINER, Bioresource Engineering Department, Oregon State University, Corvallis, OR and JAMES A. MOORE, Bioresource Engineering Department, Oregon State University, Corvallis, OR

Water Quality Monitoring Associated With Community Pasture Development in Southeastern British Columbia 40
DAVID R. GLUNS, Hydrologist, Ministry of Forests, Nelson, British Columbia and GAIL BERG, District Range Ecologist, Ministry of Forests, Invermere, British Columbia

Livestock Grazing Effects on Phosphorus Cycling in Watersheds 53
GLENN E. SHEWMAKER, Northwest Irrigation & Soils Research Laboratory, USDA-ARS, Kimberly, ID

Conceptual Criteria for Guiding Watershed Planning, Activities, And Management 61
LYN TOWNSEND, Watershed Science Institute, USDA, Natural Resources Conservation Service, Seattle, WA

An Ecosystem Diversity Matrix for Riparian and Wetland Systems 68
CAROLYN A. MEHL, Idaho Ecosystem Project, Boise Cascade Corporation, Boise, ID and JONATHAN B. HAUFLER, Timberland Resources, Boise Cascade Corporation, Boise, ID

Research to Support Sustainable Watershed Management 75
CHARLES W. SLAUGHTER, Northwest Watershed Research Center, USDA-ARS, Boise ID

Trash Rodeo: Case Study of a Watershed Effort 90
J. GARDNER JOHNSTON, Underwood Conservation District, White Salmon, WA

Development of a Stream Temperature Standard for Oregon 93
ROBERT L. BESCHTA, Department of Forest Engineering, Oregon State University, Corvallis, OR

Incorporating Drinking Water Protection Into the Watershed Approach 98
DENNIS O. NELSON, Drinking Water Program, Oregon Health Division, Portland, OR

Whose Watershed Is It? Eulogizing the Columbia River Salmon or How We Ran All the Red Lights on the Road to Extinction 113
Russell Sadler, Columnist and Commentator, Ashland, OR
Interdisciplinary Research at Northwest Watershed Research Center and Reynolds Creek Experimental Watershed 117
Charles W. Slaughter, Northwest Watershed Research Center, Agricultural Research Service, Boise, ID
Evaluating Ecological Condition of Riparian Ecosystems Using Aerial Videography 118
PATRICK CLARK[1], MARK SEYFRIED[1], CHRIS NEAL[2], and BOB HARRIS[2] ([1]USDA ARS, Northwest Watershed Research Center, Boise, ID; [2]Utah State University, Logan, UT)
Papers Presented Without a Written Submission 119

PREFACE

We are pleased to be able to present the proceedings from the symposium on Riparian and Watershed Management in the Interior Northwest: An Interdisciplinary Perspective. The purpose of the symposium was to bring together different disciplines to explore aspects of riparian and watershed management. Toward that end, the committee invited speakers from range, forestry, fisheries, and wildlife to address different topics from their disciplinary views. The readers of these proceedings should be able to get a flavor of what we were attempting. Not all of the presenters submitted papers for these proceedings. Titles of nonsubmitted papers are listed at the end so you can at least see the diversity of topics that were presented.

On behalf of the organizing committee, I would like to thank all of the sponsors, presenters, and participants in the symposium. I would also like to thank the rest of the organizing committee for their dedicated work in putting on the symposium.

We believe that these types of efforts lead to greater understanding among different professionals and that this will continue to lead us down the road to better natural resource management.

John Tanaka
Chair

RIPARIAN AND WATERSHED MANAGEMENT—WHERE SCIENCE AND POLICY SHOULD MEET

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Managing natural resources today has become a complicated process of integrating social, economic, political, and scientific information within a risk management framework. Determining the appropriate, or even acceptable, goal for a watershed is as great a challenge as understanding the ecological processes at work there. Through our actions and inactions we have transformed the landscapes of much of the arid West into systems foreign to their own disturbance processes. We are witnessing insect, disease, and fire disturbances at rates and in proportion uncharacteristic of the natural processes.

Science has much to contribute, especially if integrated scientific studies can explore the broad range of options available to society. But ultimately there must be a meeting of science and policy, where agenda-free scientific information can feed a policy debate, and choices can be made within an implementable decision framework. In this framework, personal values have weight, but the debate is about attainable outcomes associated with inputs whose costs can be predicted. This will require single disciplines shedding their mantles of superiority, joining forces with other disciplines to integrate scientific understanding at multiple scales. It will be an admission that it is not about managing individual stands, individual species, riparian areas, or even watersheds. It is about managing landscapes and the human and non-human disturbance processes that shape their composition, structure, and function. Success will ultimately depend on how we interact personally and collectively across disciplinary lines, across administrative lines, and across our personal value lines.

ALLOWING WATERSHEDS TO FUNCTION—A RIPARIAN/AQUATIC PERSPECTIVE

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ABSTRACT

Many riparian/aquatic ecosystems in eastern Oregon and the upper Columbia River Basin have been altered and affected by a wide range of land use practices. Such practices have often altered the character, processes, and functions of riparian/aquatic ecosystems. Thus, there exists a pressing need to improve and restore the functions of these systems—the reestablishment of pre-disturbance aquatic functions and related physical, chemical, and biological characteristics. Fundamental to any restoration approach is the need to remove, eliminate, or sufficiently modify those practices that have caused or significantly contributed to the degradation of riparian/aquatic systems.

Key Words: watersheds, terrestrial ecosystems, riparian vegetation, aquatic ecosystems, ecosystem functions

INTRODUCTION

The current scientific understanding of terrestrial and aquatic ecosystems often provides an important perspective from which to initially address the ecological health of watersheds and their streams. While each of these systems may have seemingly unique properties, processes, and functions; these apparent differences overlap and become considerably blurred at their interfaces. The following discussion provides an overview of some characteristics of these systems in eastern Oregon and how they function—with an emphasis on the riparian/aquatic components of a watershed (Fig. 1).

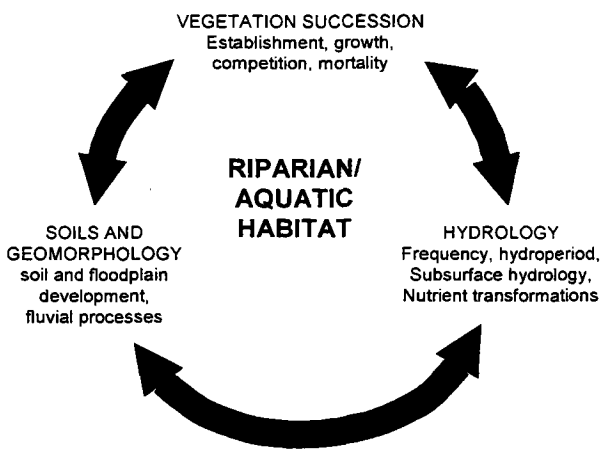

Figure 1. Processes and components of riparian and aquatic systems that influence habitat quality (from Beschta 1996).

TERRESTRIAL ECOSYSTEM

The terrestrial or upslope portion of a typical watershed in eastern Oregon can have a profound influence on the character of associated stream systems and riparian plant communities. Terrestrial areas often occupy 95 percent or more of a watershed area; thus even subtle changes in hydrogeomorphic processes may have significant effects to riparian systems, channels, and downstream areas. It is on the hillslopes that climate, vegetation, geology, topography, and soil interact to affect precipitation and snowmelt patterns that ultimately produce streamflow. Because each of these factors has considerable spatial and temporal variability across topographically diverse mountain watersheds, the pathways via which water arrives at a channel are similarly highly variable.

Much of the available precipitation and snowmelt on a given watershed will directly infiltrate hillslope soils. After accounting for replenishment of depleted soil moisture storage and evapotranspiration demands, the remaining moisture may be discharged to a stream system as subsurface flow. This water often enters a channel with chemical (nutrient concentration, pH) and physical (temperature, dissolved oxygen) properties that have been significantly altered during its movement through subsurface soils and hillslopes. During summertime periods, the relatively slow release of subsurface moisture to a stream is important for sustaining flows during seasons of normal low flow and drought; the flows are often critical in maintaining fish and aquatic organisms. The relative

constancy of subsurface flows also provides a dependable moisture source for many riparian plant communities and aquatic organisms. Thus, the subsurface flow component of a watershed's hydrology has important ramifications to riparian and aquatic ecosystems.

In contrast to the generally slower pathways of subsurface flows, overland flow exhibits short travel times and often occurs during periods of general moisture excess. High snowmelt rates, high rainfall amounts, or rain-on-snow conditions can all contribute to high moisture availability that may exceed the moisture storage and infiltration capacity of a soil. During these conditions, overland flow can occur with relatively rapid movement of water downslope towards depressions and channels. While natural factors can contribute to the occurrence of overland flow, land use activities can sometimes accentuate its occurrence and magnitude. Management activities that might accentuate overland flow include, for example, those that contribute to the loss of vegetation or litter, increase compaction, increase amounts of bare soil, increase the frequency of hot burns or catastrophic fires, and others. While the routing of water to streams via overland flow may alter peakflows, perhaps of more importance is the acceleration of surface erosion that often accompanies such events. Surface erosion typically removes those portions of a soil profile that are high in nutrients and organic matter; where surface erosion is severe or sustained, decreased long-term site productivity may develop. Accelerated levels of sediment production from hillslopes can also have profound effects on water quality, composition of streambed sediments, channel stability, and fish habitat.

The natural capturing of water by a soil system (infiltration), its storage in the soil profile (for use by plants and for release as subsurface flow), and the slow release of hillslope moisture to a stream network via subsurface pathways represent important characteristics of a healthy and hydrologically functioning terrestrial ecosystem. Maintaining high levels of above- and below-ground plant biomass, a diversity of plant species, and high amounts of litter cover at a soil surface often ensure that hydrologic pathways have not been significantly and adversely affected. Thus, a challenge to foresters, range managers, farmers, and other managers of watersheds is to not significantly affect hydrologic pathways and sediment production in the pursuit of specific land use goals. Loss of soil represents a resource loss that, for practical purposes, is irreplaceable in our lifetimes. Furthermore, increased sediment production can overwhelm the character and integrity of even a relatively intact and functional riparian/aquatic ecosystem.

RIPARIAN VEGETATION

Riparian vegetation, either as individual plants or collectively as plant communities, has a fundamental influence on local environmental conditions (microclimate, water temperature), ecosystem processes, and various ecological functions (Elmore and Beschta 1987). The above-ground component of riparian vegetation has been widely recognized for shading, sources of litter (carbon and nutrients), and woody debris recruitment. Thus, riparian/aquatic ecosystems represent a blend of physical processes (streamflow, sediment transport, energy exchanges) and structural features (floodplains, channel banks, pools, riffles) interacting with dynamic populations of riparian plant communities and aquatic organisms.

The interaction of riparian vegetation with varying flow regimes and sediment transport loads is an aspect of channel development essential to sustaining the productivity of aquatic ecosystems. In general, riparian areas with high vegetation densities are more conducive to sustaining relatively narrow, deep, and sinuous channels, the development of overhanging banks, long-term floodplain deposition, high water quality, and general food-web support. Streamside vegetation has an essential role in a number of ecological functions:

* The above-ground portion of a riparian plant community provides important roughness (hydraulic resistance) during periods of overbank flow; thus promoting deposition of fine sediments on floodplains and maintenance of channel morphology.

* Plant establishment and sediment accumulation can occur along stream margins, narrowing channels (reducing width-to-depth ratios) and thus influencing the spatial distribution and dimensions of habitat units (pools and riffles), flow patterns, effectiveness of streamside vegetation for shading a stream, temperature responses, etc.

* Vegetation anchors streambank soils with fibrous and woody root systems that resist the erosive forces of high flows.

* The interaction of flow and vegetation forms overhanging banks, thus creating important habitat niches and protection from predation for some species.

* Vegetation contributes to mid-channel and point bar stabilization, which in turn affects the long-term morphology of a stream reach.

Many of the important ecological attributes of riparian plants are associated with their root systems. Although the below-ground component of riparian plants is an essential component of maintaining or restoring healthy riparian/aquatic ecosystems, it has had limited scientific study.

From the mid-1970s to the present, considerable research effort has focused on the role and importance of large wood in forested catchments, particularly for areas west of the Cascades crest. However, channel gradients, sediment sizes comprising streambanks, peakflow hydrology, and the character of streamside vegetation for west-

side forested systems is considerably different than is found for east-side channel and riparian systems. For many riparian systems east of the Cascades crest, the occurrence of deciduous shrubs and trees (particularly willows, alders, and cottonwoods) and accompanying understories of sedges, rushes, and grasses have a much more important role in the ecological integrity of these systems that the presence of large wood. In many meadow systems, herbaceous plants such as sedges and rushes may have a dominant role in maintaining channel morphology.

HUMAN IMPACTS TO RIPARIAN/ AQUATIC ECOSYSTEMS

Because of the over-riding importance of riparian vegetation to the morphology and hydrologic functions of stream systems, significant reductions in the density and structure of these plant communities via land use practices can initiate long-term channel changes—channel incision, straightening, widening, and a general loss of stability being a common response.

With the influx of Euro-American settlers into the Pacific Northwest over the past 2 centuries and the continuing economic development of the region, watersheds in eastern Oregon and other portions of the upper Columbia River Basin have experienced a wide range of land use practices (Kauffman and Krueger 1984, Platts 1991, McIntosh et al. 1994, Wissmar et al. 1994, National Research Council 1996): the trapping of beaver, ranching, agriculture, water withdrawals, forest harvesting and roading, mining, damming, and others. As a result of these activities, impacts to riparian and stream resources have been extensive and, in some instances, relatively permanent. For example, it many not be possible to substantially reverse the effects of urban developments, highways, channelizations, dams, or other structural modifications to stream systems. Similarly, the practice of appropriating water for out-of-stream uses is deeply ingrained in western water law. Because the alteration of watersheds, riparian systems, and flow regimes has been extensive, there exist considerable opportunities for ecological restoration of many riparian/aquatic systems. Such efforts could provide not only improved habitat for fish and other aquatic organisms, but would also improve water quality and riparian wildlife habitat needs.

RESTORATION OF DEGRADED RIPARIAN/AQUATIC ECOSYSTEMS

The restoration or recovery of riparian/aquatic systems usually requires that any land use practices which have contributed to degradation be stopped or significantly modified to reduce their impacts. A principal objective in restoring degraded stream systems is to provide conditions which encourage the establishment, growth, and succession of riparian vegetation (Elmore and Beschta 1987). If successful, it will allow maximum interaction and connectivity between the riparian vegetation, floodplain surfaces, and the hydrologic regime of a stream.

It should be noted that the addition of large structural elements to degraded east-side stream systems is not likely to promote improved hydrologic functions. For example, in some situations (small streams), the addition of logs or boulders can sometimes totally arrest any natural channel dynamics. In other situations, the structural elements may greatly accentuate existing erosion and channel incision problems. These concerns are particularly acute for stream reaches in meadow and floodplain systems.

Perhaps the major challenge facing managers of many east-side riparian/aquatic ecosystems is how to initiate the restoration of those systems. To undertake ecological restoration requires an understanding of the role of hydrogeomorphic disturbance regimes that form these systems, a knowledge of land use activities that have caused degraded systems, an understanding of the important ecological role of riparian vegetation, and the identification of local reference sites that can be used to demonstrate and understand how relatively intact riparian/aquatic systems function over a range of flows and climatic conditions (Beschta 1996). For example, pre-settlement streams associated with meadow systems were often characterized as having low width:depth ratios, frequent and deep pools, high sinuosity, abundant overhanging banks, and frequent overbank flows (allowing the long-term aggradation of adjacent floodplains). Such information provides an important basis from which to address restoration issues on a wide variety of stream types in a given area (e.g., Chaney et al. 1990). Furthermore, land uses that have significantly contributed to the degradation of a particular riparian/aquatic ecosystem can often be clearly identified. Without first understanding the causes of riparian/aquatic area degradation and then stopping or minimizing the effects of those activities (Kauffman et al. 1997), proactive efforts are likely to be both costly and counter-productive.

SUMMARY AND CONCLUSIONS

Many riparian/aquatic ecosystems in eastern Oregon and the upper Columbia River Basin have been altered and affected by a wide range of land use practices. Such practices have often sufficiently altered the character, processes, and functions of riparian/aquatic ecosystems such that fisheries habitat and water quality have been significantly impaired. Thus, in many portions of the region there exists a pressing need to improve and restore the functions of these systems, i.e., reestablish pre-disturbance "aquatic functions and related physical, chemical, and biological characteristics" (National Research Council 1992). Fundamental to any restoration process is to remove, eliminate, or sufficiently modify those land use practices that have contributed to degradation.

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THE MYTH OF RANGE/WATERSHED HEALTH

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ABSTRACT

The term "health" is currently popular for describing the state of rangeland and forest ecosystems or watersheds. This use gives new life to the old organismic view of ecosystems and the balance of nature myth which have plagued natural resource management for years, but which have been largely abandoned by modern scientists. In contrast to an organism or machine, the terms "health" or "proper functioning" can only be applied to ecosystems by incorporating human value judgments into their definition. Resource assessment inevitably involves value judgments in the selection of attributes to measure and interpretation of the measurements, but rational discussion of resource management will benefit if these value judgments are identified. "Health" implies an objective standard which exists in nature and, therefore, is immune from political discussion or economic analysis. This quasi-religious view of nature does not promote rational use and management of natural resources.

INTRODUCTION

"Health" or "proper functioning condition" are terms currently popular for describing the state or condition of rangelands, forestlands, watersheds, and riparian areas (for example, see NRC 1994; BLM 1993; Sampson and Adams1994; BLM 1995; Dahm and Geils 1997). These terms generally are applied to ecosystem processes. "Integrity" is similarly used, but generally refers to "completeness" of ecosystems rather than to processes (Quigley, this symposium; West, et al. 1994). These terms, especially health and proper functioning condition, represent mythical concepts of nature which are not consistent with modern science. (One definition of a myth is: "one of the fictions or half-truths forming part of the ideology of a society"- American Heritage Dictionary.) Use of such value-laden terminology makes it difficult to separate factual data from value judgments for making natural resources policy and management decisions. In this paper I will try to explain why this is so and suggest what can be done about it.

CAN ECOSYSTEMS BE HEALTHY OR PROPERLY FUNCTIONING?

The use of health to describe vegetation or land has been around a long time. Apparently, it stems from Clements' (1916) view of plant communities as quasi-organisms, which evolved into the concept of ecosystems as finely tuned "machines," the product of a long history of co-evolution. These views were the scientific expression of the traditional concept of balance and harmony of "nature" which goes much further back in the roots of our culture (Botkin 1994). The natural resource management profession incorporated Clements' organismic paradigm into their approaches to resource assessment, and used the term "health" to describe the state of the system. For example:

"The most important characteristic of an organism is that capacity for self-renewal known as health. There are two organisms whose processes of self-renewal have been subjected to human interference and control. One of these is man himself. The other is land" (Leopold 1949).

"Range condition...is best described as the state of health of the range" (Stoddart and Smith 1955).

Yet many, if not most, plant ecologists had rejected Clements' theories of succession by the time the statements quoted above were made. McIntosh (1981) stated,

"In the sense that it (Clementsian succession theory) is most commonly criticized...it would be difficult to find a plant ecologist after 1950 who strictly adhered to it,...(although) Clements' views were perpetuated in plant, animal and general ecology textbooks...long after many plant ecologists had rejected much of their substance" (McIntosh 1980).

However, McIntosh (1980) also noted that "the core of the organismic position espoused by Clements and evident in most traditional animal ecology... is still evident in ecosystems ecology."

Rangeland and forest scientists have also generally abandoned the Clementsian paradigm (for example, see Lauenroth and Laycock 1989), but many practicing resource managers and policy makers apparently have not yet made the shift.

"It is hard today to find an ecologist who does not believe that change is the natural condition in forests. The idea of a "steady state" or a "natural balance" has long ago passed from the lexicon of forest ecology. But when it comes to policy, we find a totally different situation. Policy is still, for the most part, based upon outdated and false premises about how forests function (Botkin 1994).

"The popular perception of balance in nature persists in most fields of applied ecology and resource management to the detriment of establishment of realistic goals and guides" (Johnson and Mayeux 1992).

Use of the term "health" to describe the function of an ecosystem clearly depends on a view of the ecosystem as an organism or a machine which must be complete and in balance in order to function properly. Since modern ecologists have rejected the organismic view of ecosystems, one would suppose that the use of "health" or "proper functioning" to describe them would have also been abandoned. However, rather than being abandoned, "health" is being increasingly used to describe the state of rangelands, forests, soils, and ecosystems in resource management agencies and professions and in legislation. Recent publications admit that "health" is an inappropriate term, but then proceed to promote the concept anyway. For example:

"Rangelands are ecosystems, not individual organisms, and the use of the term "health" should not imply that simple analogies can be made between the health of an organism and the health of an ecosystem" (National Research Council 1994).

"The definition of forest health is controversial. The concept of health is well understood as applied to humans but may not be appropriate for ecosystems...Although the analogy of forest health with human health is invalid, there are general concepts applicable to all complex dynamic systems that can be used to describe and assess their condition" (Dahms and Geils 1997).

"In fact, some would argue that riparian-wetland areas are always functioning properly, no matter what state they are in. From the standpoint of fluvial geomorphology, it is true that the channel is constantly adjusting itself to the water and sediment load delivered to it from the watershed, however, BLM's definition goes beyond the processes of channel evolution and includes vegetation and biological attributes" (Bureau of Land Management 1993).

Why do these scientists and resource managers continue to use and promote a concept for natural resource policy and assessment methodology which they admit is based on scientifically obsolete concepts? Perhaps the following statement offers a clue:

"For practical reasons, it may be unimportant to define forest health in other than "fuzzy" terms (More 1996). One of the strengths of the forest health metaphor is that people can relate to it (Rapport 1995). A consensus on the need for forest health is sufficient to bring together resource managers, lawmakers, and the public. Most people have an intuitive idea of what constitutes a healthy ecosystem; at least, they believe they can recognize an unhealthy one when they see it" (Dahm and Geils 1997).

So, here we have it! "Health" is a catchy phrase, a "sound bite," that will capture the attention and support of the public and lawmakers. Who could not be supportive of efforts to maintain or improve "health" of the ecosystem? Never mind that the term is ill-defined (undefinable?) and unscientific and, therefore, does not promote careful analysis of desired resource benefits and the actions required to achieve them. But that is the way much of our public discourse occurs in the media.

WHAT IS HEALTHY OR PROPERLY FUNCTIONING?

To assess resource condition it is necessary to have a standard of comparison (Laycock 1989). Traditionally resource managers in the United States have looked to the past, to the "pristine" condition which presumably existed before the arrival of European man, when ecosystems were supposedly "undisturbed" by man and therefore "healthy" or "properly functioning." "Based on Aldo Leopold's writings, Monnig and Byler (1992) said forest health is best measured by how its patterns and rates of change compare to historic patterns" (O'Laughlin, et al. 1993). Range condition assessment has generally compared present vegetation composition to the climax vegetation for a particular ecological site. Climax was considered a stable equilibrium condition in the absence of "abnormal" disturbance, e.g., disturbance related to European man's influence. However, there is a large body of literature that shows that the conditions prior to European settlement:

1. Are not well known. Little exists to reconstruct the pre-European conditions, and the selection of a time frame for this comparison is arbitrary. By the time most European settlement and observation occurred, changes due to introduction of the horse and human disease had altered Indian populations and culture significantly. Market hunting and trapping had also affected wildlife populations.
2. Pre-European conditions were neither "natural" nor stable. Indians had significant impacts on the vegetation and wildlife through hunting, farming, and use of fire. Changes in vegetation have

occurred also due to climatic influences and biotic invasions throughout recent geologic time, and there is no reason to suppose that these changes had stopped prior to European settlement.

3. "Pristine" conditions were not necessarily "good" given the desires for goods and services from natural resources of modern society. Uncontrolled wildfires or uncontrolled grazing by herds of wild herbivores may have been "natural" but neither is necessarily desirable for modern land use objectives, even in national parks. It is interesting to study historical patterns, e.g., fire frequency, but that does not imply that historical patterns are somehow good and establish a desirable fire frequency for present condition. Existing changed environmental conditions and our land management objectives may dictate otherwise.
4. Finally, pre-settlement conditions are not necessarily achievable even if we find them desirable. Invasion and extinction of species, changes in climate and soil, and other factors may make "restoration" of such conditions impossible or at least economically unfeasible.

Recognizing that pristine or climax conditions are not reasonable standards for judging resource condition, some (e.g., Range Inventory Standardization Committee 1983) have suggested using potential natural vegetation as a standard for condition assessment. Potential natural vegetation assumes succession to an equilibrium state in the absence of any further man-caused disturbance, i.e., it takes into account past changes in environment and biota. But many of the criticisms of climax or pristine standards also apply to potential natural vegetation as a standard, including the fact that this concept still postulates predictable, linear, constructive, and autogenic processes. Nevertheless, agencies are still using these concepts to rate "ecological status" of upland ranges and "proper functioning condition" of riparian-wetland areas. For example, a BLM manual (Bureau of Land Management 1993) on riparian-wetland management states:

"Assessing functionality is based upon an area's capability and potential....Capability—The highest ecological status a riparian-wetland area can attain given political, social, or economical (sic) constraints....Potential —The highest ecological status an area can attain given no political, social, or economical constraints; often referred to as the 'potential natural community' (PNC)."

Given the dynamic nature of riparian systems, and the frequency of natural "disturbance" due to flooding characteristic particularly of those in arid/semiarid areas, it is not clear to me that the concept of PNC has much relevance to "proper" functioning of the system. But riparian systems do not seem to be fundamentally different from upland systems in this regard, except that obvious "disturbance" is perhaps more frequent and dramatic in riparian systems than in uplands.

ECOSYSTEM CONDITION OR HEALTH IS A VALUE JUDGMENT

"Defining an optimal condition for an ecosystem is not possible....Using the term healthy to describe an ecosystem infers there is a state that is good for the system. A state other than that defined as good must necessarily be bad and consequently unhealthy. However, good or bad ecosystem states cannot be defined scientifically and can only be based on the kind of ecosystem desired by society" (Wicklum and Davies 1995).

"Health" or "proper functioning condition" are not attributes of an ecosystem; they are interpretations based on human value judgments. West, et al (1994) also indicated that all efforts to assess ecosystems involve value judgments. The attributes selected for measurement and the criteria for interpretation of these measurements as good or bad, acceptable or not, depend on the objectives of the assessor. The objectives of rangeland assessment can be divided into 2 categories:

1. Sustainability—Resource managers (and society in general) share a concern that present land uses should not degrade the capability of the system to provide goods and services in the future, if possible (Landscape evolution, climatic change, etc. impose limitations on this ideal). This concern establishes an objective which, though still a human value judgment, is more or less universally shared.
2. Desired values, goods and services—Resource managers and the people they serve wish to know the status of goods and services currently supplied by the land with respect to what is practically possible to supply. Such knowledge guides decision making, management action, and investment. Not everyone agrees on how to value goods and services; some place a higher value on economic values and others on aesthetic or "ecological" values. These differences are not subject to scientific resolution, but are political in nature. The problem with the concept of "health" and "proper functioning condition," as presently used, is that the issues of sustainability and desired outputs are not separated.

The Society for Range Management's Unity Task Group (1991,1995) recommended that rangeland be assessed using:

1. Site Conservation Status—soil/vegetation attributes related to conservation of the soil on a given site. Conservation was described as a tolerable apparent rate of erosion given the natural

potential of the site for erosion. Erosion was considered the major site-specific cause of irreversible degradation for most arid/semiarid rangeland sites. (Loss of plant or animal genetic resources is another cause but usually cannot be determined on a site-specific basis.)

2. Desired Plant Community—represents the plant community type selected from all community types known to be capable of existing on a site as best meeting management objectives determined by landowners and other interested parties. This concept clearly recognizes that the desired plant community is based on human values and objectives, provided it also meets the site conservation requirement.

The Natural Research Council Committee on Rangeland Classification (1994) agreed with Unity when they stated: "Rangeland health should be a minimum ecological standard, independent of the rangeland's use and how it is managed. If rangeland health is protected, a variety of uses could be appropriate for any particular rangeland." However, they recommended interpretation of multiple attributes of rangeland systems related to:

1. Soil stability and watershed function
2. Distribution of nutrient cycling and energy flow
3. Recovery mechanism

SELECTION OF ATTRIBUTES

In my opinion, attributes selected for measurement or observation for interpretation of rangeland condition or "health" should meet several requirements:

1. Attribute should have a known relation to the interpretation to be made. For example, ground cover has a recognized relation to sheet erosion, or production per hectare of forage plants has a known relation to carrying capacity for certain animals.
2. Attribute should be capable of observation or measurement, preferably in the field. For example, sheet erosion cannot be observed directly in the field most of the time, and its measurement depends on instrumentation over long periods of time. Therefore, erosion rate is not a practical attribute for rangeland assessment, and we measure a surrogate attribute such as ground cover instead.
3. Observer bias should be minimized, i.e., observations should be repeatable if performed by different people at different times. This requirement does not rule out use of professional judgment, but it does require that observers should have adequate professional training and experience to make judgment calls.
4. Observation of attributes should be separated from interpretation, i.e., the attribute should be defined in objective terms so that data can be re-interpreted as objectives change or new knowledge becomes available. For example, ground cover should be recorded in cover classes or percentages, not as "adequate" or "inadequate."

CRITIQUE OF COMMON INDICATOR ATTRIBUTES

There are a number of indicators used for assessing ecosystem health or proper functioning condition which may or may not be appropriate. The following is a sample of some recommended by one or more of the current efforts to assess ecosystem status.

1. Animal species—It has been claimed that presence or abundance of certain animals is an indicator of overall ecosystem health, e.g., the goshawk is an indicator of the health of the ponderosa pine ecosystem in the Southwest. I see no scientific or logical basis for this viewpoint. Abundance of goshawk may indicate quality of the habitat for goshawk, but this species could be eliminated from the system and it is likely that ecosystem functions would be scarcely noticeable. Did elimination of the passenger pigeon from its former habitat result in ecosystems which cannot now be considered "healthy?"
2. Habitat for fish and wildlife; habitat for endangered species (BLM 1993; BLM 1995)—Fish and wildlife habitat and the preservation of endangered species are management objectives established by law and public demand. Lack of habitat for one or more of these species does not mean that the entire ecosystem is necessarily "unhealthy" or losing its capability to produce goods and services. Unless such a connection can be established, these attributes are inappropriate for rating ecosystem function.
3. Diversity (NRC 1994; BLM 1993; BLM 1995)—Diversity of species, life forms, age classes is often given as an indicator of "proper" function for both uplands and riparian areas. It is possible that such diversity could be related to such things as bank stability in riparian areas (i.e., diversity of rooting habits and depths), or to reproduction of plants desirable for such purposes. However, in most cases these attributes are included because they relate to desired plant communities for wildlife habitat or other purposes not directly related to ecosystem sustainability, and they are thus inappropriate.

4. Nutrient cycling, photosynthetic activity (NRC 1994, BLM 1995)—These are not attributes of ecosystems capable of direct observation in the field, nor does there yet seem to be any reliable surrogate attribute that is observable. Thus any assessment of these processes is highly subjective. Most of the examples involve built-in value judgments. Moreover, other than nutrient retention in the system, which is not the same as nutrient cycling, the relationship of these processes to irreversible degradation of ecosystem productivity is not apparent.

5. Water quality (BLM 1993, BLM 1995)—Clean water is a valid management objective, but the quality of water in riparian systems has no universal or necessary connection to "proper function" of ecosystems. Sediment in the water may have undesirable consequences for fish habitat or human aesthetic values, but if there is an ecosystem function problem it likely relates to the nature or condition of the uplands contributing runoff to the stream. Likewise, temperature, biological contamination, chemical contamination, etc. may be of concern because of their effects on human health and enjoyment or their impact on fish/wildlife habitat. If these attributes are to be used to rate "proper function" of riparian systems, then their relation to hydrologic function should be demonstrated.

6. Native/non-native species (BLM 1993, BLM 1995)—Presence of non-native species is included as a criterion for rangeland health and riparian function. However, there is no basis for assuming that occurrence of non-native species negatively affects basic ecosystem function in either case. Invasion of non-native species may change the plant/animal community but it is not necessarily less productive, less sustainable, or less desirable from a management standpoint than the native community. For example: The California annual grassland is composed mostly of non-natives that replaced native perennials, but the productivity of the soil has apparently been maintained. Crested wheatgrass, Lehmann lovegrass, and other non-native species have replaced native grasses with no apparent degradation of site potential. Salt cedar is now being protected in some places because it constitutes nesting habitat for the southwestern willow flycatcher, an endangered species. Non-native species should be assessed according to their effects on desired management outcomes, not because they are relatively late arrivals in the plant community.

CONCLUSIONS

1. Ecosystem "health" and "proper functioning condition" are unscientific, value-laden terms which hinder rational analysis of resource problems, decision making, and development of sound policy. These terms should be abandoned.

2. Many of the indicators used to assess "health" or "proper functioning condition" have no known or consistent relationship with the concept of ecosystem sustainability, but relate instead to values or management objectives shared by some interests, but not all.

3. All assessment of both riparian and upland ecosystems is human value driven. We should try to make a distinction between the attributes measured and the interpretation or values assigned to them.

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Using Proper Functioning Condition Analysis to Promote Collaborative Watershed Management

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The USBLM, USFS, and NRCS have joined together to form a coalition with the objective of protecting and restoring riparian health. In order to do this a process for assessing riparian health using a common vocabulary and set of definitions developed by USBLM has been established.

The agencies depict natural riparian-wetland areas as resources whose capability and potential is defined by the interaction of three components: 1) vegetation, 2) erosion/deposition, and 3) hydrology. The process of assessing whether a riparian-wetland is functioning properly requires an interdisciplinary team (IDT) that should include soils, vegetation, and hydrology expertise. Biologists also are normally included in the team because of the high fish and wildlife values associated with riparian-wetland areas.

Riparian-wetland areas are in proper functioning condition (PFC) when adequate vegetation, landform, or large woody debris is present to dissipate stream energy associated with high water flows (thereby reducing erosion and improving water quality), filter sediment, capture bedload, aid floodplain development, improve floodwater retention and groundwater recharge, and develop root masses that stabilize streambanks against cutting action.

Riparian-wetland areas that are in functional condition but have an existing soil, water, or vegetation attribute that makes them susceptible to degradation are considered functional at-risk. Riparian-wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows and thus are not reducing erosion and improving water quality as described for PFC are defined as nonfunctional.

The PFC process provides a means to inventory and monitor riparian-wetland condition and trend. The process can be applied to both lentic and lotic environments anywhere from the arctic to the tropics. A standard checklist is used to complete the PFC assessment by an interdisciplinary team. The PFC assessment can be used to determine successional stages of stream development and aid in establishing desired future condition goals.

A national riparian team has been established in 1996 and is stationed in Prineville, Oregon. Training in the use of PFC is being provided in all western states. International interest in the process has prompted individuals from Canada and Australia to learn about the PFC assessment process. For additional information, contact: USBLM National Riparian Team, P.O. Box 550, Prineville, OR 97554 (541-416-6722).

How Human Values, Filters, and Perspectives Affect Riparian Management

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ABSTRACT

While much recent theoretical and empirical attention has been given to complex ecosystem processes, much less attention has addressed another complex system: natural resource management agencies. Given that land management agencies are mandated to oversee ecosystem principles, amidst much societal and ecological conflict, it behooves us to gain a better understanding of natural resource agencies. Value orientations of organizations and individual employees are important ingredients in understanding how organizations function. It is a common assumption that the values of public agencies are representative of those of the public. Public attitudes and values have evolved to encompass ecosystem and increasingly biocentric philosophy. Furthermore, individual employees also have their own values, which may or may not match their organization's value system. Although current agency policy statements clearly reiterate the views of managing the lands for a diversity of values, it is uncertain whether internal agency actions reflect stated agency policy. This discussion will focus on values (in general), then center on values within agencies and with the public.

Keywords: organizational culture

INTRODUCTION

We all have our own ways of viewing the world, as individuals and as members of organizations. It is exciting to witness the convergence of multiple agency and disciplinary viewpoints at this riparian and watershed conference. Furthermore, as a sociologist, I welcome the opportunity to help bring a social science perspective to resource management.

The views we hold are shaped by our culture and values. Furthermore, those views shape the issues people see as important and ultimately influence their behavioral outcomes. Such cultural views give our environment meaning. For instance, when looking at a river, an angler, birdwatcher, and jet ski enthusiast are likely to see very different landscapes depending upon their world view. As scientists, interpretations may be represented as to stream health or functionality. When looking at an open field, a real estate developer may see a new subdivision, parking lot, or golf course; a farmer may see a booming crop; a community resident may see a city park, including soccer fields; and someone else may see a wetland. Why does the same stretch of land or river evoke such varied and often conflicting responses? According to Greider and Garkovich (1994:1): such "landscapes are the symbolic environments created by human acts of conferring meaning to nature and the environment, of giving the environment definition and form from a particular angle of vision and through a special filter of values and beliefs. ... These landscapes reflect our self definitions that are grounded in culture."

Not only do individuals exhibit values, so too do institutions and organizations. Organizations and individuals display their values in many written or spoken ways, but most profoundly through their actions. Furthermore, individual employees within organizations also have their own values, which may or may not match their organization's value system. Today's discussion will focus on how values are expressed in attitudes and behavior, both among the public sphere and within natural resource agency agencies.

OVERVIEW OF VALUES

What do we mean by values? The term is used in a variety of contexts, and has been applied to both living and non-living organisms. As sociologists, we also have many definitions, yet most definitions encompass: "General, shared conceptions about what is good, right, appropriate, worthwhile, and important with regard to conduct, appearance, and states of existence" (Ferrante 1998).

Values do not occur in a vacuum. They are typically a product of our culture. Within any culture, there may also be subcultures which introduce values (which may or may not be consistent with the dominant culture). It is difficult to identify values in and of themselves.

Researchers often examine behaviors as reflections of one's values. However, the causality between values and behavior is never certain, as will be discussed below.

It is through our culture that information or the learning process is transmitted. "Culture consists of the shared ideas, values, and beliefs that together provide a kind of blueprint for appropriate behavior in the group. Cultural values both reflect and reinforce institutional structures" (Cable & Cable, 1995:11). Culture primarily consists of shared knowledge (what we know about the world), beliefs (what we think is true), values and attitudes (what we think is good and what we like or dislike), social norms (how we expect people to behave), and technologies (our recipes and tools for doing things).

Culture is transmitted via social institutions. A social institution is a formalized system of beliefs (ideas, values, beliefs, technologies) that address some enduring human concern or problem. Social institutions in modern societies include the economy (how do we make a living?), political system (how do we provide order and resolve conflicts?), family (how do we regulate reproduction and ensure that people care for each other?), educational system (how do we transmit culture and skills across generations?), religion (how do we provide answers for ultimate questions and moral cohesion in society?).

Socialization plays an important role in shaping values. Socialization is the process whereby we learn the values and behaviors of our culture. Socialization begins at birth (and some would argue in utero) and is a lifelong process. Socialization of perceptions and values occurs within the above social institutions, as well as "by a [variety] of primary (friends, family, co-workers) and secondary (public figures, mass media) influences which function as filters in the diffusion of information in the community" (Hannigan 1995:95).

Socialization is constantly taking place. People are exposed to new information which they may or may not adopt into their world view. Such is the case when we are socialized into our professional identities. We learn the appropriate values and behaviors that will yield positive results in the work place. These organizational values may or may not be consistent with our personal values. This potential dilemma will be explored in the following discussions of environmental values and natural resource management agencies.

ENVIRONMENTAL VALUES

The theoretical approach used in this discussion to understand environmental values is based on social constructionist and symbolic interactionist views of values (Berger and Luckman 1967; Greider and Garkovich 1994; Hannigan 1995). These theoretical paradigms suggest that values are human creations, and values towards the environment are not inherent. "A social constructionist approach ... recognises the extent to which environmental problems and solutions are end-products of a dynamic social process of definition, negotiation and legitimation both in public and private settings" (Hannigan 1995:31).

How people construct environmental knowledge provides their groundwork for claims to individual rights; public rights; their view of management, technology, and society; and of what they think the environment ought to be. "In other words, human social behavior is more directly related to symbolic constructions and definitions of situations than to external environments per se. People exist in natural environments, but they live and act in worlds mediated and constructed by cultural symbols" (Schutz, 1932/1967) (Harper 1996:35). So when we look at an environmental landscape, such as the river or open field described above, the variety of definitions of those places can be explained by understanding the symbolic constructions emanating from different cultural identities. Therefore, any landscape has the potential to exhibit multiple values and is transformed into culturally meaningful definitions, which may conflict. Since there is such a strong cultural identification with the natural environment, when potential changes are proposed, a cultural group may feel its identity is also potentially changed. Furthermore, the ability of any cultural group to assimilate or accommodate new changes into their world view will vary.

American views of environmental issues have shifted in the past 30 years from an orientation of the environment and natural resources as separate from humans (e.g., humans are exempt from the environment), to a view that social systems are interconnected with natural/environmental systems (new ecological paradigm) (Dunlap and Mertig 1991; Steel et al. 1994).

Furthermore, public values are changing. In general the trend is more toward preservation (ecology) than utilitarian (economic); however, economic values still tend to dominate in resource agencies. Thus, there is a lack of coordination between agencies and public opinion. We need to reexamine the current management practices (which are the expression of organization values) and respond accordingly.

Public environmental attitudes and values are examples of shifting belief systems about what the world ought to be. Although the current environmental paradigm may have been a shift in perspective for some cultural groups, for others, it is consistent with their world view.

Although we can document via opinion polls, voting, etc. what the American public perceives as important environmental issues, it is important to remember the notion of "Most Important Problems." In the United States, we are currently in an economic and political climate where many people within our society have met their basic needs (e.g., along Maslow's hierarchy of

needs), and can now extend their concerns and energy to "other" problems, such as environmental issues. Granted, environmental issues are likely to be more salient to people whose economic and cultural livelihoods are dependent upon natural resources. However, when we are looking at the broader public (in particular urban areas), we also see such a trend toward increased concern over the environment. When the public is asked questions on the importance of maintaining a clean or healthy environment, people are likely to answer "definitely important."

However, when people are asked to rank the importance of environmental problems with other social problems (e.g., education, crime, the economy, world hunger, etc.), the emphasis is likely to shift to non-environmental issues (depending upon their state of meeting their basic needs). Therefore, to understand, for instance, why an environmental issue is salient, it is necessary to take a broader view of where the environmental issue is situated among other social issues, as well as an understanding of the social climate of the cultural group.

When trying to understand the connection between people's values and behavior, there are several assumptions made. First of all it is often assumed that changing attitudes will lead to a change in behavior. Second, it is often assumed that increasing one's knowledge will lead to a change in attitude. Thomas Arcury (1990) reviewed the literature on this issue and conducted a study on environmental attitude and environmental knowledge to examine these assumptions. His results supported the assumptions. There was an association (albeit weak) found between environmental knowledge and attitude. However, the more interesting result was the finding that there existed a low level of knowledge in the first place! This suggests that public perceptions (filtered primarily via the media) may not be based on sufficient knowledge of the issues, yet the public is gaining increased political power in the decision-making process. Given the increased participation of the public in decision-making, it behooves those involved in the discussion to ensure that all participants are basing their opinions on the same information. Therefore, a forum for knowledge exchange needs to exist. This means agency personnel need to not only share information, but listen and place value on local knowledge.

VALUES WITHIN NATURAL RESOURCE AGENCIES

Within organizations, whether an academic institution, IBM, Nike, or a natural resource agency, employees are likely to adopt a value system that emphasizes their technological expertise to understanding complex systems. This is likely to also include professional bias/perspectives; after all, employees are typically very well trained in their fields of expertise (Roper and Kennedy 1989). Furthermore, as professionals, employees are assumed to be rational in their decision-making, thereby minimizing the role of values—either personal or organizational. However, this traditional organizational paradigm is shifting. As noted by Vining and Ebreo (1991:180) "[t]he idea that managers (or anyone else) can make decisions impartially is questionable because they may be partial primarily to their own values." Yet, organizational value systems, due to their complex bureaucratic nature, are slower to change than individual value systems. Bullis and Kennedy (1991:544) point out that "studies show that there are both strengths and liabilities inherent in [a] strong, cohesive professional culture as managers must cooperate in multidisciplinary environments. Managers must deal with multiple value contexts. By understanding differences in the values which guide decision making, wildlife managers should be better able to negotiate in such complex arenas."

Employee demographics are changing in many resource management agencies (Decker et al. 1996). Employees, typically male, from rural areas, who were socialized via single-discipline oriented value systems, are facing retirement. Entering personnel and employees currently moving through the ranks are likely to be personnel with more diverse backgrounds (e.g., from urban/suburban backgrounds), more women, and various multidisciplinary philosophies (Kennedy and Quigley 1989). As Decker et al. (1996:75) notes: "new professionals ... do not necessarily share the traditional values ... many are interested in managing fish and wildlife for a variety of values, sometimes different from the values that motivated their predecessors."

Not only are we witnessing a shift in the demographics of agency personnel, but also of the enactment of management philosophies (Wattendorf 1997). Although multiple use values have been part of agency stated goals, management policy has not always followed such goals. What I would like to turn to now is a series of studies of USDA-Forest Service value orientations as a way to illustrate organizational values.

In 1986, the USFS published its vision statement "Caring for the Land and Serving People" (USDA-Forest Service 1986). Subsequent studies have examined whether the stated values were endorsed by employees (Kennedy and Quigley 1989, Cramer et al. 1993). Kennedy and Quigley (1989) compared a sample of entry-level employees with senior employees and found that the majority of both generations supported the values in the vision statement; yet they also acknowledged that the USFS reward system did not strongly support these values. That is, the agency was not putting its money where its mouth was.

In 1991 a follow-up study, which was more representative of the entire USFS population, was conducted. A recent study by Kennedy et al. (1992) examined values

held by USFS employees. In this study, a representative sample of 1,626 USDA-Forest Service (USFS) employees evaluated how well the agency reward system supported publicly stated USFS values and multiple use priorities. When asked to rank their perception of how the USFS values multiple uses, how the public values multiple uses, and how respondents personally value multiple resources, most respondents still view the USFS as placing a high priority on traditional commodity uses, primarily timber. However, they see themselves and the public as more supportive of non-commodity uses such as recreation and wildlife and believe these values deserve more agency attention (Cramer et al. 1993).

Beyond examination of attitudes toward agency priorities, respondents addressed issues of organizational reward structures by indicating attitudes and behaviors that are actually rewarded versus what the agency publicly praises. Among 20 value priorities (including USFS loyalty, ability to meet targets, promote USFS image), employees indicated that professional competence should be most rewarded (71%), even though only 37% of the respondents felt that it actually was rewarded. Furthermore, only 23% of respondents believed that promoting a USFS image should be rewarded, yet 58% indicated that it was being rewarded. Employees in various positions shared similar perceptions that the USFS most rewards loyalty and meeting achievement targets; whereas they believe their agency should most reward professional competence and care for healthy ecosystems. Obviously there is some discrepancy in what the agency says it rewards and what employees perceived to be rewarded. The constraints of congressional budgets and mandates also affect what values/behavior are rewarded.

DISCUSSION

Natural resource managers, as well as the public, are constantly evaluating decisions made about their environment, "but they do not decide simply on some objective basis of right and wrong, safe and unsafe. Instead, decisions on environmental use are reached in a social context: they are influenced by such factors as cultural values and attitudes toward the environment, social class, and our relationship to others" (Cable & Cable, 1995:5). A social constructionist and symbolic interactionist approach to understanding values suggests that if proposed management changes can be incorporated in such a way as to coincide with existing symbolic and cultural definitions, or in a manner that produces minimal conflict, then the negative social impacts will not occur.

In order to minimize value conflict, it is important for multiple parties to work cooperatively, and to maintain an atmosphere of open communication. Where such successes exist, they need to be rewarded, both publicly and in formal organizational reward structures. Natural resource agencies, such as those involved in riparian and watershed management, also need to evaluate what their stated values are, and what values are expressed and rewarded. In many ways agencies have to "practice what they preach." It is not enough to have policies in place that espouse an understanding of the public's perceptions and their values, but how are such policies displayed, both within management agencies, and to the broader public? When the public suspects a "lip service" phenomenon is taking place, trust erodes.

Another challenge of natural resource managers is to examine whose values are dominating the decision-making process and the outcomes (e.g., who gets invited to the table, and who do they represent; also who gets to make the final decision?). "In the context of landscapes, power is the capacity to impose a specific definition of the physical environment, one that reflects the symbols of a particular group of people" (Greider and Garkovich 1994:17). A related issue is to recognize the legitimization of group leaders; that is, do they truly represent the values of their constituency, or are there personal agendas being advocated.

It is also important for managers to remember that just as "one size does not fit all, no one set of values fits all" members of a subculture. That is, not all ranchers have the same values, not all environmentalists have the same values, and not all resource managers share the same values.

Several articles are now available (and the Journal: "Human Dimensions of Wildlife") that examine the role of values and resource management agencies (e.g., Brunson 1992; et al. 1995; Cramer et al. 1993). In general, these articles suggest the need for agency personnel to better understand the interconnectedness of people, their values, and the resource. Furthermore, resource managers need to stay abreast of changing public values, as noted by Brunson (1992:295): "... natural resource managers need to pay better attention to social values ... What we in forestry have learned, to our chagrin, is that the failure to effectively identity those values and manage for them can lead to unacceptable consequences—unacceptable for the resources themselves, and for the agencies and people who manage them." What I suggest is not only an identification of values, but a development of an understanding of the broader social context in which values are embedded.

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CALLING ALL EXPERTS: USING SCIENCE IN WATERSHED POLICY AND DECISION MAKING

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ABSTRACT

Contemporary watershed problems are among the most complex and challenging environmental issues for society to address. Not surprisingly, policy and decision makers now often look to the scientific community to provide useful information and direction. The wider public also generally supports this approach, as they rate scientists among the most credible sources of information about natural resource issues. The scope and nature of watershed issues make the effective use of science in decision making much more than a simple matter, however. For example, not only is a broad array of technical facts and uncertainties important, but there are also some key values for which preferences can vary widely among both individuals and institutions. This complexity is clearly seen in most larger watersheds that include highly diverse private and public ownerships and management objectives.

Thus, even where the public is provided with relevant scientific facts, the political arena may remain the primary setting for resolving watershed issues that involve a broad range of public values and preferences. This situation may also politicize the availability and use of scientific input, e.g., both decision makers and scientists may selectively use or interpret technical information to support their personal or political preferences. However, careful attention to such trappings can help generate more complete and objective input and application. This can include establishing explicit criteria for evaluating the quality of scientific input, as well as for its use in policy and decision making.

These and other points about science and policy and watershed issues are discussed further in the references that follow. Information about obtaining copies is available through the author.

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An Environmental History of Riparian Areas in Southeast Oregon

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ABSTRACT

Restoring riparian areas requires that we examine not just the ecological and hydrological processes at work in a riparian area. We must also pay attention to the human history that shaped riparian landscapes. Mining, fur trapping, removal of beaver, dam construction, drainage and irrigation for agriculture, road building, logging, grazing, wildlife management, and urbanization have profoundly shaped riparian areas. Using the Blitzen River of southeast Oregon as a case study, this paper examines the changing ways different communities of people have envisioned the boundaries between water and land, and the ways they have altered these places with the hopes of making them more clearly one element or the other.

Key words: Environmental history, riparian areas, Blitzen River, Harney County, Harney Basin, range history

Why are riparian areas in the inland West in such poor condition, and why do people disagree so fervently about the best techniques for their restoration and management? Finding answers to these questions requires that we examine not just the ecological and hydrological processes at work in a riparian area. We must also pay attention to the human processes shaping riparian landscapes. Any ecosystem is a product of its history, and that history includes cultural as well as ecological forces. Mining, fur trapping, removal of beaver, dam construction, drainage and irrigation for agriculture, road building, logging, grazing, wildlife management, and urbanization have profoundly shaped riparian areas. Yet landscape change comes about not just because people graze cows, dam rivers, mine for gold, drain meadows, plow up river bottoms, or cut down trees, but because they do all these things in a world where nature and culture, ideas and markets, tangle together in complex ways. To restore damaged riparian areas, we need to understand not just the ecological and hydrological processes that have been disrupted. We need to understand why those disruptions occurred.

One piece of land is never entirely separate from another, even if we think that a string of barbed wire forms an effective barrier. A bit of dirt kicked free by a cow finds its way into a stream and eventually gets deposited 20 miles away. A salmon gets its gills clogged by that sediment, far from where the cow had grazed. Moving water connects these places. The places where water and land meet—the riparian zones—mediate these connections, and so these riparian zones have effects far outside their boundaries. Riparian zones make the boundaries between water and land more complex, yet these complexities have often been hard for people to comprehend. Even though riparian areas received much of the brunt of Euroamerican settlement in the West, for generations riparian areas were conceptually invisible. Riparian areas are not really water and they are not really land, so they fell outside normal scientific categories of analysis. This had major implications, not just for research, but also in the physical world of creeks and cows.

In this paper, I will examine the changing ways different communities of people have envisioned the boundaries between water and land, and the ways they have altered these places with the hopes of making them more clearly one element or the other. Rather than summarizing the ecological effects of each of the historic events affecting riparian areas across the inland West, I will develop one case study, that of the Blitzen River in southeast Oregon.

When bird watchers now flock to Oregon's Malheur National Wildlife Refuge, they find a teeming wilderness along the Blitzen River. Winding river channels, riparian meadows, willow thickets, ponds, and marshes create an oasis in the high desert of the northern Great Basin, used each year by an average of 25 million birds (Duebbert 1969). To the visitor, the Blitzen seems like a supremely wild refuge from both desert aridity and human industry.

In 1934, when the US Fish and Wildlife Service bought these lands, the picture was very different. After 4 decades of overgrazing, irrigation withdrawals, grain agriculture, dredging, and channelization, followed by several years of drought, the valley had become a dust bowl (Brimlow 1951). Attempts to increase production by making wet lands drier and dry lands wetter had stripped the willows and cottonwoods from the banks, imprisoned the river in a ditch, and dried up the meadows and marshes. People did not fare any better than the land: ranches failed, livestock starved, homesteaders went bust, and the primary occupation in the valley became suing your neighbor over water rights. Water control was an unmitigated disaster.

Restoration, in constrast, has been a success. After 63 years of federal management, the once dessicated riparian meadows are again lush and green, water moves through the wetlands, and flocks of waterfowl have returned to blacken the skies. But for all its appearance of wildness, this is an intensively managed landscape. Refuge staff have restored the land, not back to any natural or historic state, but to a complex mosaic of managed habitats that never existed before federal management. Ironically, all the same water control techniques that devastated the land in the first decades of the 20th century are now used by the refuge managers for restoration. Tracing changes in riparian management in the Blitzen watershed can help illuminate some of the complicated boundaries between nature and culture in the history of water in the West.

The Blitzen watershed is part of the northern Great Basin where the rivers flow, not into the sea, but into briny lakes. In 1826, when Ogden's fur trappers first entered the Malheur Basin, they found a confusing maze of streams, channels, wetlands, bogs, alkaline lakes, fresh water lakes, roaring rivers, forests, grasslands, and gloomy expanses of greasewood wastelands. Without that water system, this would have been another barren desert, unable to support more than a very few animals and even fewer people. With the water, it became the center for what was briefly the largest cattle empire in America, and what became some of the most bitter battles between cattle barons, homesteaders, irrigators, ranchers, and environmentalists—all focused on who would win control of the riparian areas.

The Blitzen River begins high on the west slopes of Steens Mountain, a 9,773-feet-high, 50-mile-long fault block that tilts 5,400 feet above the surrounding desert, catching winter snows and summer thunderstorms. After roaring off the mountain through a series of narrow gorges, the river enters a nearly level valley, where it meanders 56 miles across a wide floodplain until reaching Malheur Lake. During spring snow melt, the waters rise over their banks and spread over the bottomlands, flood-irrigating lush riparian meadows where Great Basin wild rye once waved 6 feet high. Along the Blitzen, riparian areas include groves of cottonwoods and aspen, willow shrub communities, meadows of rushes, sedges, wire grass, and Great Basin wild rye, and tule wetlands in the river's floodplain.

For thousands of years, the river moved across the entire flood plain, using a set of sinuous channels that changed from decade to decade. These riparian communities were anything but stable; floods, changes in rainfall, and changes in animal activities led to dramatic annual changes in the bottomlands. Some years the marshes were lush and green and stretched from one end of the valley to another; the basin filled with water. Other years little snow fell on Steens Mountain, and by early summer the lowland streams ran down to a trickle, the riparian meadows turned brown, and the marshes slowly dried. Some years the water was so high that numerous pools and ponds formed in the valley, perfect for brooding waterfowl. Other years few pools formed, and waterfowl rearing habitat was minimal.

Beaver had been critical in shaping these changing landscapes. When Peter Skene Ogden came looking for beaver in 1826, between 60 and 400 million of them still ranged over American riparian habitats (Naiman et al. 1988). Beavers in the Blitzen watershed cut down trees and shrubs and built dams—as many as 15 to 25 dams per mile of creek in prime habitat (Naiman et al. 1986). Dams slowed the water flow, retained tremendous amounts of sediment and organic matter in the stream channel, and regulated nutrient flows. The wetlands they created buffered floods and helped prolong the late summer flow of streams (Naiman et al. 1988). Beaver ponds in various stages of creation and decay formed a shifting mosaic of diverse vegetation communities across the watershed, playing a critical role in shaping the landscape.

Beaver alterations made watersheds more resistant to disturbance, as well as more resilient—quicker to recover from disturbance. By buffering the effects of floods, drought, and fire, and by serving as a source of nitrogen in a nitrogen-limited landscape, beavers had profound effects on the landscape that greeted Euro-Americans. But ranchers and homesteaders who eventually followed Ogden into the valley, unlike the fur trappers, saw the beaver as a nuisance, to be removed from their own water projects—which in many ways, closely resembled the beaver water management projects.

Although the Paiute had used the area extensively for thousands of years, few Euro-Americans settled in the region until the 1870s. Many whites hated this land's mixture of barrenness and fecundity. Odgen spat out in his journal: "a more Gloomy Barren looking Country I never yet seen" (Ogden 1826). But others saw promise in the lush bottomlands. Jesse Harritt, an emigrant who joined Stephen Meek's disastrous 1845 attempt to find a shortcut to the Willamette Valley, wrote in his journal when he reached the Malheur basin: "As we advanced this

morning the beautiful scenery increased; this valley is one of the most sublime places I ever saw....the soil is rich and beautifully set with fine grass, intermingled with patches of sage" (Harritt 1845). Most Americans, however, were put off by stories of marauding Indians, the area's remoteness from other settlements, and the nature of the land itself. The years from 1854 to 1869 had been particularly wet. While reports of northern Great Basin's grasslands had attracted California ranchers to eastern Oregon, they avoided the Blitzen Valley, for it seemed too wet and swampy to be safe for unattended cattle (French 1964).

In 1872, that isolation changed with the arrival of Peter French. French had started out in 1870 as a hired hand breaking horses for the Sacramento "Wheat King" Hugh Glenn. Within 2 years, Glenn trusted French enough to make him manager for his expansion into Oregon, and in June of 1872, French headed up the Sacramento River, looking for lush grasses and room for cattle. What he saw in the Blitzen delighted him. From a discouraged prospector named Porter, French bought a brand, a few cows, and the informal rights to graze the Blitzen valley (French 1964). By the time he died in 1897, murdered by a homesteader over contested riparian lands, French had built up those holdings into an empire of 45,000 cattle and 132,000 acres.

French was a progressive rancher for the times, determined not to follow the standard practice of letting the cattle roam lose most of the year. French had his vaqueros ride close herd on the cattle, which made it much safer to run cattle in the wet bottomlands, where untended cattle could founder in the mire. His vaqueros trailed the cattle up the mountain in the spring, following snowmelt from the winter bottomlands up to the high peaks, the cattle eating the new protein-rich shoots of grass as soon as they appeared. He spread water over his drier riparian meadows with flood irrigation in the spring, increasing the growth of native hay that he could cut and store for the winter. Since the sagebrush uplands did not seem particularly productive to French, he drained tule marshes, using the water to flood out the sagebrush, which dies when its roots are submerged. With his water systems, French made the uplands wetter and the swamp lands drier, and both of them better for cattle production (French 1964, Ortega 1931).

French's success attracted the attention of others. Within a few years, the Malheur basin began to be settled by other cattle ranchers, and homesteaders soon followed. French, however, was the only rancher in the region able to provide winter hay, since he controlled most of the suitable riparian meadows. The hay allowed him to prosper during the hard winter of 1879-80, when most of his neighbors went bust. He bought them out one by one, steadily consolidating his holdings in the valley, until he controlled nearly all the water sources and riparian areas in the watershed.

By controlling the lower elevation water sources, French controlled who could graze cattle on Steens Mountain, since cattle needed daily sources of water. But sheep did not depend on perennial streams, so French could not prevent their access to the mountain. By 1901, when the Bureau of Plant Industry sent out an inspector, David Griffiths, to report on grazing conditions, Griffiths estimated that at least 500 sheep per square mile were grazing on the 400 square miles of mountain pastures, and staying there for at least 4 to 5 months of the year. In other words, 182,500 sheep were on the mountain, for a total of nearly a million sheep months that year. As Griffiths wrote in his report: "To say that the southern portion of the region is overstocked would be putting the matter very mildly....On the whole trip of three days we found no good feed, except in very steep ravines" (Griffiths 1902). In areas, "there was practically no more feed than on the floor of a corral. We passed two areas at least 2 miles in extent in which even the surface of the ground was reduced to an impalpable powder" (Griffiths 1902).

Griffiths noted that intense competition for early-season grazing led to particular pressure on riparian areas. At higher elevations, "the destruction of the [riparian] shrubbery, all too scanty in this region, had a potent influence on the lowland meadows and the mountains themselves, both in relation to the conservation of moisture and the protection of the surface soil from the erosive action of water. The destruction of the vegetation means vastly more than simply depriving cattle of food..." (Griffiths 1902). Competition for water, and particularly irrigation of hay meadows for winter feed, had reached the point that "the rivers do not reach the sinks, and the small tributaries from the mountains often do not reach the main channel, for all of the water that succeeds in getting down to the fertile sage-brush areas near the river bottoms is used...in irrigation" (Griffiths 1902).

What little productive feed was left on the private riparian bottomlands was only to be found hidden "among the willows, along ditches, and in low swampy areas which remain uncut....It is needless to say that these areas are taxed to their full capacity....A piece of ground from which a crop of hay is removed during the summer will not usually maintain its productiveness in any region if every particle of vegetation remaining is pastured off during the fall and winter seasons"(Griffiths 1902). Griffiths argued that overgrazing effects would never improve "as long as there is no inducement for anyone to do aught but get all he can out of the little that the country does produce." The only solution he saw was to provide more grass, so there would be less competition for the resource.

Griffith's inspection tour came at a time when overgrazing and water projects, combined with a few dry years, had sparked an explosive situation among valley

residents. As early as the 1880s, the water levels of Malheur Lake had begun to fall as more water was diverted for irrigation, and the lands between the high water mark—the meander line—and the waterline became contested territory. Above the meander line was French's land, but between the line and actual lake levels, homesteaders began to settle, first grazing a few cows, then trying to grow alfafa or grain. When homesteaders first moved onto this unsurveyed land in the early 1880s, French raised no objections. In 1894, however, he claimed riparian rights and informed homesteaders they had to leave. When they ignored him, he started suits in the Federal court in Portland, and when the first case was found against him, he appealed the verdict (French 1964, Ortega 1931). Some homesteaders cut French's fences and killed his cattle; he retaliated by buying their lands when they could not make payments.The situation escalated until finally, in 1897, a homesteader named Ed Oliver rode up and shot the unarmed French in full view of his men. The jury found in favor of Oliver, supporting his claim that he acted in self-defense.

The empire French had built did not last long with his death. In 1906, the French-Glenn Livestock Company was sold to Henry L Corbett, the Oregon senator; he soon sold to Swift & Company, the meat packing company, which reorganized the holdings into the Blitzen Valley Land Company. Hoping to subdivide their holdings and sell them off as small farms, the Blitzen Valley Land Company built extensive irrigation facilities and dredged 20 miles of the river (Ivey 1986). Ivey notes that channelization "changed the water regime...eliminating the curving oxbows of the river channel from the river's influence...[leading to] extensive reduction of riparian habitat along the old watercourses and some new development of willow communities along irrigation facilities" (Ivey 1986). The development scheme never paid off, however. In 1916, the operation reorganized yet again, this time into the Eastern Oregon Livestock Company, running about 20,000 head of cattle on the P ranch. Unlike Peter French, the managers failed to put up enough winter hay, and they lost 40% of the cattle in the next two winters. Feral hogs filled the tule marshes and bottomlands, and then sheep were brought into the valley, which did not exactly improve conditions. The effects of all this human, animal, and machine activity were soon apparent. In the early 1930s, drought hit, and combined with overgrazing, conversion to grain agriculture, dredging, channelizing, and elimination of much riparian habitat, much of the valley was reduced to dust. The land was sold once again, this time to the federal government, who wanted the Blitzen River water rights to protect water levels on the Malheur Lake Bird Reservation (Ivey 1986).

With the goal of restoring waterfowl nesting habitat in the valley, John Scharff (refuge manager from 1935 to 1971) began extensive engineering projects for the control of water. Using the labor of the Civilian Conservation Corps boys, Scharff's staff bulldozed new ponds for chick rearing habitat, built dams to hold water, dug ditches for irrigating meadows, and extended 100 miles of canals along both sides of the valley to supply water reliably to the entire floodplain (USFWS 1941, USFWS 1946, Ivey 1986). Instead of a system of wandering channels, where in some years only part of the valley might be wet, they tried to create a landscape where they could always control which meadows were wet, which ponds stayed full of water, and which meadows were allowed to dry out. In 1951, George Brimlow described the engineering in terms that evoke the enthusiasm of the age for such projects: "Engineering feats accomplished wonders for the sanctuary of migratory waterfowl and the haven of feathered and furry life. A concrete dam spans the Blitzen at the south end of the refuge....The Blitzen serves as a canal for twenty eight miles, there being 100 miles of canal. Water is held at various levels, the impounding of it in a box canyon making Boco Lake. Dikes and other improvements assure proper control and protection" (Brimlow 1951).

The Fish and Wildlife Service hoped to construct an empire of nature, a complex machine aimed at increasing waterfowl production. But trying to maintain this "proper control and protection" led refuge staff into continued complications. Until Scharff retired in 1971, anything that seemed to detract from waterfowl production was eliminated. When carp got into the lake and began making their way up the Blitzen watershed, stirring up sediment and eliminating the sago pondwood that ducks required, refuge staff drained the lake and sprayed rotenone to kill the carp, along with anything else that was in the water (such as the now-endangered Lahotan cutthroat throat). When coyote and raven populations soared, lowering duck nest success, refuge staff set out poisoned bait, and then had to contend with rodent predation on eggs. When beaver returned to the valley and blocked up the irrigation ditches, staff trapped them out, even though the irrigation system was trying to replicate what beaver had created in the first place (Cameron 1996, USFWS 1941, USFWS 1946, USFWS 1971).

Cattle numbers had probably the greatest influence on habitat condition. Until World War II, numbers stayed low, and habitat dramatically improved—not just from cattle exclusion, but from increased rainfall and decreased diversion for grain agriculture and flood irrigation of the wild hay meadows. But beef demand increased with the war, and John Scharff, who had grown up on a ranch, was a great proponent of the idea that livestock could be a tool to create good waterfowl habitat. The number of AUMs on the refuge rapidly soared, increasing nearly 600% over 3 decades from 21,602 in 1941, to 123,807 in 1971 (USFWS 1941, USFWS 1971).

When cattle congregated in the Blizten's riparian areas during the seasons that young grasses were not available, they turned to palatable shrubs such as willows, alders, young aspen, and cottonwoods. Their hooves trampled the creek beds, removing enough of the riparian vegetation that streams eroded. As cutbanks developed, the water table dropped and channels widened. With the drop in the water table, more riparian vegetation declined and sagebrush moved in, increasing rates of erosion. Instead of shrubs, trees, sedges, lush meadows, and fertile bottomlands, the result was incised creekbeds, eroding cutbanks, and wide shallow streams that dried up earlier and flooded more fiercely in the spring.

With the return of cattle to the reserve, increasing grazing opportunities soon became a major goal of the Scharff administration. Willows seemed to get in the way of maximum cattle production, so soon Scharff decided willows had to go. By the 1950s and 1960s, "weed" control became one of major objectives of refuge administration. Willows were cut, mowed down, and sprayed with 2,4-D to open up the view for birders, to remove predator habitat, to increase mowing efficiency in the hay meadows, and to increase the number of acres that could be put into full production. But the most important reason was to decrease competition for water. Woody riparian plants are phreatophytes, extending their roots into the water table, using a great deal of water (USDA 1967). As one USDA report argued, "Many people believe that the high consumption of limited water supplies by phreatophytes is one of the most serious problems in the West" (USDA 1967). The Fish and Wildlife Service initiated willow control programs, spraying thousands of acres each year in the basin with 2,4-D to eliminate the water hogs.

Riparian hardwoods are thirsty plants, which was often why people cut them down, thinking they were stealing water from livestock and more useful trees. But using water does not always mean reducing the supply for everyone else. Instead, riparian vegetation can allow streams to continue flowing longer. Even while they steal water, those plants increase the available supply to other plants. Riparian plants make the boundaries between water and land more complex, slowing water flow, keeping dirt from flooding the streams. Their leaves shade the streams, reducing water temperatures. Their branches and dead wood fall into the water, creating deep pools of scoured gravel where fish can spawn, trapping debris, forming dams. Refuge staff used to think all this was bad—the point of a stream was to move water from point A to point B as efficiently as possible. But the more people tried to simplify streams by channeling them and piping them and cleaning them up, the more the waters dwindled away. Riparian zones make the boundaries between water and land more complex, yet these complexities have often been hard for people to comprehend.

In the 25 years since John Scharff retired, management of Blitzen River riparian areas has become less clumsy, but no less manipulative. Now, instead of using bulldozers to channelize the river, the refuge staff is trying to figure out ways to use bulldozers to return the river to its old meanders. Willows are being planted instead of being ripped out, but herbicides still play an important role, removing vegetation that might compete with desired native species. The irrigation and water control system grows ever more elaborate, since without it, much of the habitat for rare and endangered birds would be lost. Coyotes still get shot and ravens still get poisened when they threaten the sandhill cranes, since the cranes are rare and their predators are not. Flood irrigation still waters the meadows, but now it creates hay for bird cover, not just for cattle (USFWS 1990).

Most importantly, perhaps, the refuge is no longer trying to fix a single pattern of ponds and meadows and wetlands in place. Instead, they are trying to manage variability back into the system, by moving water around each year, alternating which meadows are dry and which are wet. Yet this variability is allowed only within strict limits: for example, the river is now encouraged to meander a little, but not enough to threaten the canals and brood ponds.

In the Blitzen Valley, creatures have been manipulating the flow of water for a very long time. Ironically, all the same water control techniques that devastated the land in the first decades of the 20th century—irrigation, draining, ditching, damming, and livestock grazing—are now used by the refuge managers to restore the land. Even more ironically, perhaps, those techniques are to a certain extent "natural"—for they are variants on non-human processes that shaped the landscape.

How then do we decide what manipulations are desirable, and what manipulations are likely to be disastrous, if the category of natural is no longer particularly useful here? Restoring ecological integrity is probably a more useful concept than simply trying to restore back to the past "natural" ecosystems. But what exactly is ecological integrity, in places of such frequent change and human activity? Learning about how past ecosystems functioned can certainly help us define ecological integrity, but it is dangerous to pick one aspect of the landscape and attempt to put that back into place. That is what the managers at Malheur tried to do for decades, and it led them into continually mushrooming complications. Trying to restore variability to the system, while fraught with complications, is a much more promising direction, since variability is a critical aspect of the integrity of riparian areas. A fixed, wholly stabilized creek is a dead creek: a mere conduit of water.

Perhaps the most interesting thing about riparian areas is that they are, by definition, places of constant change, because water is such a mobile element. The boundaries of riparian communities shift from day to day, as the waters move among these plants, pulling apart one clump

of soil, depositing another clump a few feet downstream. Each year, cycles of seasonal changes reshape the riparian lands, as winter storms pull up entire forests, and spring snow melt swells the streams, undercutting banks and reshaping sand bars. We live in a world of change, both ecological and human. The vestiges of the past haunt current managers of riparian zones, for any watershed in the West is the product of how its predecessor was destroyed.

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Ecosystem Health for the Forests of Eastern Oregon

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The forest ecosystems of eastern Oregon have been significantly altered by past management and fire suppression practices and in many places do not support healthy forests, streams, and watersheds. Sensitive species are at risk, and the threat of catastrophic fire constitutes a hazard to local populations. Timber-dependent communities have seen drastic declines in their resource-based economies.

Background: Eastern Oregon, and much of the inland Northwest, was blessed with extensive stands of old growth pine covering millions of acres on low and mid-elevation sites when Europeans arrived during the past century. Over the past 80 years, forest management policy, characterized by active fire suppression, road building, and harvesting of valuable old growth pine, has transformed these forests to their present state. Today we are left with overstocked stands of young fir and pine, thousands of acres of dead and dying timber infested with insects, degraded watersheds, and an unacceptable risk of catastrophic fire. Thousands of miles of riparian areas have been damaged by harvest and grazing practices, as well as by roading and urbanization.

FOUR GOALS FOR EASTSIDE FOREST MANAGEMENT

Governor Kitzhaber has laid out four goals to guide restoration efforts on the eastside:

1. Restore the health of the forests themselves
2. Restore the health of riparian systems and watersheds
3. Provide wood to local communities
4. Reduce the risk of catastrophic fire

Development of the Proposal: In the spring of 1995 Governor Kitzhaber appointed a diverse group of highly respected scientists from throughout the Northwest to make recommendations on ways to restore ecosystem health and provide wood to communities in an environmentally sound manner. That panel issued a report that reflected a consensus among the scientists on what needs to be done to improve the health of the forests, streams, and watersheds of the eastside.

In May of 1996 the Governor appointed an Eastside Forest Advisory Panel, consisting of a very diverse group of eastern Oregon community leaders, to make recommendations on ways the United States Forest Service might implement the findings of the scientific panel. The panel has visited numerous sites throughout eastern Oregon and provided recommendations to the Governor.

The Governor's Proposal: The main premise of the 11-point proposal is that there are key areas of agreement where we can move ahead now to restore ecosystem health and provide wood to local communities without threatening non-timber resources.

One of the critical elements of the proposal is that we need to use active management to treat stands that are overstocked, or have been inappropriately converted from pine to fir.

At the same time, the Forest Service should plan and implement operations first in less controversial areas, avoiding roadless areas, sensitive fish habitat, and old growth areas.

Monitoring of the effect of forest treatments is imperative, and will allow the Forest Service to learn from its efforts, establish a track record, and make adjustments where necessary.

Where the proceeds from the sale of timber associated with a treatment strategy are not enough to pay for the work needed, the Forest Service should have access to money to fund the project. The income from a sale should not be enhanced by the addition of valuable timber whose harvest does not promote ecosystem health objectives.

STRATEGY FOR ESTABLISHING GOVERNOR'S PROGRAM THIS YEAR

1. Work with Congress to secure funding to finance ecosystem health restoration efforts.
2. Work with the U.S. Forest Service to ease administrative barriers to restoring ecosystem health in forests, streams, and watersheds; reducing the risk of catastrophic fire; and providing wood to local communities.
3. Work with local Forest Service officials to focus forest treatment programs on ecosystem health restoration and away from projects that tend to hinder restoration or are not broadly supported by local stakeholders.
4. Use the "Oregon Option" to identify obstacles to achieving ecosystem health restoration goals and to modify administrative procedures to aid in achieving these goals.

5. Coordinate with the Interior Columbia Basin Ecosystem Management Project. Implement the Governor's proposal in a way that enhances the long-term planning effort contained in the Eastside Project.
6. Request that the Forest Service report on an annual basis on the implementation of the Governor's proposal.

PROPOSED EASTSIDE FOREST HEALTH STRATEGY—JUNE 1997

1. There are broad areas of potential agreement about goals for restoration of ecosystem health to the forests of eastern Oregon.
2. Ecosystem health includes the health of forests, streams, and watersheds. Achieving and maintaining good water quality and quantity should be a priority for all forest management activities.
3. Ecosystem health may be improved through active management in overstocked stands which have suffered from fire exclusion and highgrading of large trees. Thinning of small-diameter green trees is an important component of active management for forest health and will help make sales economically viable.
4. Be responsive to the diversity of communities dependent on forest resources including Native Americans, timber-dependent communities, and recreation and tourism sectors.
5. Plan and implement operations first in less controversial areas. In the short run, avoid operating in roadless areas, near fish habitat, and in old growth areas.
6. For ecosystem health restoration activities to truly succeed, monitoring and learning from these efforts is essential. The Forest Service, the research community, Congress, the Administration and the Governor's Office should join together in assuring that we learn from the management strategy employed to restore ecosystem health. Monitoring actual results will be critical to justifying ongoing active management.
7. Cumulative effects analysis should include all ownerships within a watershed, where possible. This may be accomplished by working with local watershed councils.
8. Active management includes cutting trees, riparian area planting, reforestation, prescribed fire, road obliteration, stream rehabilitation, and protection of sensitive areas.
9. Use of low-impact, cost-effective equipment is an important element in effective restoration. The Forest Service, federal government, and the state should provide incentives that encourage the use of such equipment.
10. Timber salvage may be an important component of ecosystem health restoration and fuel reduction strategies to the extent that it promotes ecosystem health goals.
11. Where the costs of ecosystem health restoration efforts are not paid for by timber sale proceeds, funds should be made available to finance these activities on a priority basis.

POLICY AND MANAGEMENT LESSONS LEARNED: 25 YEARS OF THE OREGON FOREST PRACTICES ACT

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ABSTRACT

While the primary policy direction of the Oregon Forest Practices Act (FPA) has been constant, the Act's riparian and watershed protection practices have significantly evolved. Several trends related to the evolution of the FPA are: (1) the rate of rule-making has increased over the past decade, (2) the rules are getting more lengthy and complex, and (3) conflict over resource management is increasing, and the issues are being engaged with more polarization. There are a number of key lessons that the Department of Forestry has learned through the evolution of riparian and watershed rules. These lessons include that change can proceed best when there has been demonstration of a problem, a practical solution has been developed, and an enlightened portion of the regulated community understands, accepts, and supports the solution. However, as the issues addressed become more complex, the science to support policy choices about level of protection is often inadequate or inappropriately used. It has also become increasingly difficult to write simple rules for the complex and dynamic systems and issues we are now being asked to address. Riparian biological and ecological values often conflict with landowner objectives for the land, particularly in the interior Northwest. Creating a common interest is required for changes to practices to be implemented. It is the Department of Forestry's belief that changes to practices don't always need to be mandated. Newer concepts such as "ecosystem management" and watershed analysis are being suggested for application through the Forest Practices Program.

Key words: Forest practices, rule-making, science supporting rule-making

Over the course of its first 25 years, the primary policy (though with some minor modifications to its wording) of the Oregon Forest Practices Act has been "to encourage economically efficient forest practices that assure the continuous growing and harvesting of forest tree species and the maintenance of forestland for such purposes as the leading use on private forestland, consistent with sound management of soil, air, water, fish and wildlife resources..." (ORS 527.630)

While the primary policy has been constant, the Act's riparian and watershed protection practices have significantly evolved. The last major change to the riparian rules occurred in 1994.

For the past 6 years I have been involved in the Forest Practices Program dominantly working on riparian and watershed issues. My belief is that the Forest Practices Act and Program have some very important strengths. However, it is also my belief that the program is on a policy "precipice," and some of these strengths may be lost for a number of reasons. These strengths include:

1. The program is generally well accepted by the regulated community.
2. The program is efficient (operators are not burdened with unnecessary red tape).
3. The rules are objective based (giving operators flexibility to apply appropriate practices based upon the site conditions).
4. The program is adaptive (as needs have been demonstrated, the rules have been changed).

TRENDS

One trend related to the Forest Practices Act (FPA) is that the rate of rule-making has increased over the past decade. One consequence of this trend is that program acceptance by the regulated community may at times be compromised. Additionally, the increased rate of rule-making has directed agency resource away from implementation support and technology transfer, further eroding landowner understanding and support. Concern about riparian and watershed protection standards continues to be raised, despite inadequate time since rule implementation to measure the effectiveness of the current rules. A

context for these concerns often indicates disagreement with the policy of the Act and/or desire to apply broader scale planning requirements.

A second related trend is that the rules are getting more lengthy and complex. The recent water protection rules (1994) are an example.

Another trend (or this possibly could just be my singular perspective) is that conflict over resource management is increasing and that issues are being engaged with more polarization. The conflicts increasingly include disagreement across all three of the following factors: facts, interest, and values. Under the FPA processes for addressing issues, we have traditionally been able to reach enough consensus for effective action on most issues. The increased issues polarization, most frequently seen with issues associated with federal programs, will make it much more difficult for the Board of Forestry to craft solutions that enjoy broad support.

The increased rate of rule-making and increased conflict has produced increased uncertainty with several resulting potential trends such as:

1. While overall timber harvest rates are down, non-sustainable rates of harvest have occurred on non-industrial private forest lands, particularly in the interior Northwest.

2. Possibly decreased management investment

3. Possibly a greater rate of conversion of forest land to other uses

KEY LESSONS LEARNED

There are a number of key lessons that the Department of Forestry has learned through the evolution of riparian and watershed rules. I will try to go through each of these lessons in some order while trying to give you some perspective about each of the lessons.

Key Lesson 1: Change can proceed best when there has been demonstration of a problem, a practical solution has been developed, and an enlightened portion of the regulated community understands, accepts, and supports the solution.

Demonstrating a problem requires agreement about facts. As we get into more "holistic" or complex issues, the facts become less certain.

To develop a practical solution, the regulated community must be directly involved. Field trips and site visits are important to develop an appreciation for the limits of technology or to understand possible unintended consequences of a proposed action. Such an approach often is useful to get common understanding of the facts.

How do you enlighten an adequate portion of the regulated community? To create understanding, acceptance, and support and to change behaviors requires tremendous effort. One common assumption that many people have is that other's actions are mostly driven by selfish desires. I hear this assumption applied to landowners' actions all the time. People say; "Why doesn't the landowner do this or that (for example, keep his/her cows out of the riparian area); if he/she doesn't it is because he/she is a greedy so and so." My experience is that many people do not do the things we hope they might for a number of reasons besides selfish desire. These include:

1. The landowners do not know of the importance of an action and/or have never been asked how they can help.

2. The landowners as a group or as individuals have interpreted the facts differently.

3. The landowners do not know how to implement the action.

4. The landowners do not have the resources to implement the change.

Keeping these reasons in mind is important to produce the enlightenment that we need.

A parallel to Lesson 1 is the difficulty in gaining acceptance by rural communities of edicts or programs developed from places such as Salem, Portland, or Washington D.C. Working within the community to develop new programs or rules is desirable to gain acceptance.

Key Lesson 2: Science to support policy choices about level of protection is often inadequate or inappropriately used.

Public value changes and associated legislative mandates often precede thorough scientific understanding or monitoring results. Conclusive monitoring or research demonstrating a problem are frequently absent, and thus, actions may be directed mostly based upon assumptions or beliefs.

As we move into more complex problems, the level of scientific uncertainty increases. Dueling science occurs, making decision makers highly uncomfortable about taking action.

Some people that want to rely on science aren't willing to allow the time and/or apply the discipline to critically review the science and appropriately use it. There often is a lack of critical review of referenced scientific literature. The limitations of the research are often overlooked. Once seemingly scientific assertions are made in summary documents, they live on because they are rarely challenged. In some cases such assertions have become "mainstream" doctrine.

For example, in one federal document it is asserted referencing 1983 research done by Dr. Walt Megahan that "A likely impact of timber salvage after wildfire is an

increase in water runoff, erosion, and landslides because of increased snow accumulation and faster snowmelt" (NOAA 1995). However, the Megahan (1983) study evaluated the effects of clearcutting and subsequent wildfire on the hydrologic function of granitic slopes in Idaho. The study showed an increased snow accumulation and melt following clearcutting and a subsequent wildfire. That coupled with increased soil moisture storage at the end of the growing season, did increase the depth and volume of the soil saturated zone as well as the volume and rate of subsurface flow runoff. However, the study had nothing to do with the effects of post-fire timber salvage operations. Based upon Dr. Megahan's knowledge, there are no data to show that cutting of dead standing timber increases snow accumulation and melt rates (personal communication). In fact, Dr. Megahan has suggested in personal communication that the opposite would likely occur because of reductions in aerodynamic drag and the amount of longwave radiation input to the snowpack. It is not difficult to find many more examples of this problem.

Key Lesson 3: Riparian biological and ecological values often conflict with landowner objectives for the land (particularly in the interior Northwest).

Due to the relative dryness of the interior Northwest, riparian areas and floodplains have been a focus for achieving landowner objectives such as cropping, grazing, or timbering. The dynamic nature of the natural system is often viewed by the landowner as a negative in meeting such objectives. When taking testimony about the 1994 Water Protection Rules, one of the most common fears was about trees falling in a stream and causing bank erosion. Creating a common interest among these competing objectives is necessary. However, creating such a common interest is going to be very challenging. I believe that purchase of conservation easements and other similar approaches offers some hope.

Key Lesson 4: Changes to practices don't always need to be mandated.

Back to the common and false assumption that others' actions are driven only by selfish desires. Without identifying and addressing the root causes underlying the behaviors we want to change, we will not succeed. Positive results are achieved if landowners know why they are being asked to do something, they are provided conclusions based upon facts that are reasonably interpreted, they know how to implement the action, they understand the benefits that will accrue directly or through some added incentives, and they have or are provided the resources they need to change.

Key Lesson 5: It is difficult to write rules for complex and dynamic systems.

A complaint I frequently receive is about the complexity of the current rules. As we move into more complex issues such as cumulative effects, there will be greater risk of even more complex rules. One downside is that more complex rules are much tougher to field test and the possibility of unintended consequences increases. Another downside is that people will be less likely to accept and support such rules, let alone implement them. As complexity increases, the Department of Forestry's ability to administer the rules is also challenged. Complex rules aren't all bad—they offer opportunities for flexibility in meeting site-specific needs and a range of resource objectives. However, complex rules do need to be supported by clear objectives and to be balanced by a range of site-specific alternatives

Key Lesson 6: It is hard to get off the "bandwagon" once it gets rolling.

The current enviro-bandwagon is carrying concepts such as "ecosystem management" and watershed analysis, and those on the bandwagon suggest that these concepts should be applied through the Forest Practices Program. By raising concern about the "bandwagon," I do not mean to demean these concepts. However, the bandwagon, particularly the federal bandwagon, is often not the best ride for non-federal lands. One only needs to reflect upon past actions carried by a bandwagon to feel a sense of concern.

For example, watershed analysis may ultimately be found to be a very valuable tool. But the efficacy and value of this tool has not been well studied. Federal agencies have expended considerable resources on watershed analysis. The only evaluation of watershed analyses that I am aware of concluded that around 50 percent of the conclusions reached as part of the studied analyses were not supported by the data and that conclusions contained within an analysis often contradicted other conclusions (Dr. Leslie Reid, USDA Forest Service, personal communication).

The possible application of actions developed for federal lands to non-federal lands needs to be treated skeptically. The purpose of the lands is different and the practicality of implementing actions may vary greatly.

In closing, the Forest Practices Act is a program that seeks to balance resource and economic interests on non-federal forest lands. Conflict in this process is inevitable, but I think it is wise to disagree, agreeably, and to keep Abraham Lincoln's words in mind; "With malice toward none; with clarity for all...let us strive on to finish the work we are in."

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RESPONSES OF SELECTED CENTRAL OREGON STREAMS TO CHANGES IN GRAZING MANAGEMENT

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ABSTRACT

In the late 1970s, approximately 400 miles of streams were inventoried by the Prineville District of the Bureau of Land Management for in-stream and riparian condition. Following the initial survey, grazing management was changed to exclusion or to a different season of use for those reaches in poor condition. During the summer of 1994, the riparian portion of the survey was repeated on 11 stream sections. The surveyed streams varied in composition of community types, gradient, elevation, grazing management, disturbance history, influence of beaver (*Castor canadensis*), and restoration efforts. Four-hundred meter (1/4 mile) stream segments were resurveyed between matching points from the old survey. Total riparian area increased an average of 0.62 ha (1.52 ac) per mile of stream. Lower gradient reaches had greater increases in riparian area than higher gradient reaches. Bare soil at the water's edge decreased an average of 775 m (850 yd) per 1.6 km (1 mile) of stream. Lengths of cutbank were reduced where they had been extensive, but were recorded where there had been zero in the initial survey. With one exception, results indicated an upward trend in both grazed and ungrazed riparian reaches.

Key words: riparian area, grazing management, livestock exclusion, cutbank length, bank damage, riparian survey, gradient, beaver, trend, central Oregon

The recovery of deteriorated riparian areas has received considerable attention in recent years. Debate over how to achieve recovery of these systems has been intense. Livestock grazing has been suggested as perhaps the most influential human-caused impact on western riparian ecosystems (Elmore and Kauffman 1994). Cessation of livestock grazing has been suggested by some (Kauffman et al. 1997) as the single most effective approach to restoring salmonid habitats. The basis for that statement was primarily results of studies by the senior author and his graduate students on the effects of grazing on woody riparian species. They state that livestock exclusion has demonstrably resulted in a rapid recovery of riparian vegetation. However, the authors themselves note that appropriate livestock grazing management is of major importance for the proper functioning of many western riparian zones. Elmore and Kauffman (1994) state that livestock grazing can be present in some areas while streams are improving. They further state that there are many problems with using exclosures as a solution to halt overuse by livestock. Those problems include wildlife access and the cost of construction and maintenance. In the 1970s, livestock exclosures were constructed by a number of researchers and land managers to evaluate the potential for change in the absence of livestock grazing (Elmore personal communication). Results were often dramatic. However, grazing management outside the exclosures was generally not changed, and the dramatic improvements within the exclosures were compared to a continuation of inappropriate grazing outside the exclosures. The conclusion has often been that livestock grazing is not compatible with improving deteriorated riparian areas or maintaining those currently functioning properly. A more appropriate conclusion should be that exclusion is an improvement over inappropriate grazing. Inappropriate grazing for riparian zones is often growing-season or year-long grazing with essentially no active management. In a number of reviews, growing-season and year-long grazing have been described as devastating to riparian conditions (Skovlin 1984, Elmore and Beschta 1987, Kovalchik et al. 1991, Platts 1991). This paper reports results from a study that was designed in part to evaluate the responses of selected central Oregon streams to change in grazing management.

METHODS

In the late 1970s and early 1980s, Wayne Elmore (currently BLM's National Riparian Specialist) and others under his direction conducted a qualitative and quantitative survey of the in-stream habitat, riparian vegetation, bank condition, water quality, macroinvertebrates, and

animals present (via pellet counts) along more than 400 miles of stream within the Prineville District, Bureau of Land Management. In 1994, a resurvey of the riparian and bank condition portions of the original survey was conducted on 17 of the original 400 miles. The streams resurveyed were four sections of Bear Creek and one section each of Camp, Pauline, Indian, Roba, Bronco, Beaverdam, and Heisler Creeks.

In the 1994 survey, the methods of the previous survey were followed as closely as possible. A member of the original survey team was brought back to Prineville for 2 days to review the methods of the original survey with the 1994 survey crew. Wayne Elmore, in charge of the original survey, was also available as a resource.

In the original survey, photographs of the stream and riparian vegetation were taken every 400 meters (1/4 mile). These photographs helped document representative community types and typical features. In 1994, these photographs were retaken where original photo points could be located. Additional photographs were taken of representative community types and defining features.

The riparian survey identifies different types of stream vegetation in broad categories (e.g., sedge-grass, willow-sedge, grass-forb). Old and secondary channels, springs, and seeps were identified as separate communities, as were communities above large, stable beaver (*Castor canadensis*) dams and gabions. Actively eroding banks (cutbanks) were recorded as estimated lengths. Lengths and widths of the communities were measured by means of a pacing stick calibrated to the surveyor's pace. Widths were measured periodically, with a pacing stick, at points of the stream that represented the average width, typically several per 400 m section. As in the original survey, bank damage was interpreted as bare soil at the water's edge. Lengths were visually estimated and classified by their source as natural (erosion), trampling (trails, hoof-sheared collapsed banks, etc.), and other (beaver, road fords, logging, etc.). If the stream was dry at the time of the survey, the channel edge was used.

SITE AND MANAGEMENT DESCRIPTIONS

BEAR CREEK SECTIONS 1-4

Grazing in the area has occurred since the 1800s and was typically summer-season-long use until the late 1970s. Willow (*Salix* spp.)-birch (*Betula* spp.) and sedge (*Carex* spp.)-rush (*Juncus* spp./*Eleocharis* spp.)-grass communities dominated the riparian vegetation in presettlement conditions.

Section 1 is approximately 4.8 km (3 miles) long with a low gradient (<2%). It was initially rested for 6 years. Since then a three-pasture (all three riparian) rotation system has been implemented with turn-on scheduled for peak flow (late January/early February) and removal from the third pasture by around April 1. Junipers were cut on parts of immediately adjacent uplands. Juniper (*Juniperus occidentalis*) rip-rap was placed on cutbanks in 1982.

Section 2 is approximately 4.0 km (2.5 miles) long with a moderate gradient (2-4%). It has been excluded from grazing, with good compliance, since 1978. Juniper rip-rap was placed in 1982.

Section 3 is approximately 0.4 km (0.25 mile) long with a low gradient (<2%). It has been in a winter-spring, deferred rotation grazing system since prior to the 1978 survey.

Section 4 is approximately 2.0 km (1.25 miles) long with a low gradient (<2%). It has been in winter-spring grazing since prior to the 1978 survey. Livestock are moved out of the pasture prior to seed stalk emergence.

CAMP CREEK

The section surveyed is approximately 1.6 km (1.0 mile) long with low gradient (<2%). Four gabions were installed in Camp Creek in the fall of 1985-86, two of which were in the section resurveyed in 1994. The riparian corridor was fenced in 1985/86. In February of 1986, a large event washed out all four gabions with repairs made 2 years later on only one. Eroding banks downstream of the gabions were rip-rapped with juniper. The communities upstream and immediately downstream of the gabions comprised 1.3 ha of the total riparian area for the 1.6 km reach. Beaver activity occurs in the upper portion with small unstable dams built of sage (*Artemisia tridentata*) and juniper.

Livestock graze in the spring of the year since 1987. Before that time, grazing occurred in the late summer for 8 years, preceded by 5 years of spring grazing.

The bank damage portion of the Camp Creek survey was not completed until 1988, after a 1987 summer storm event, and was done by a different crew than the rest of the surveys.

INDIAN CREEK

The surveyed portion of Indian Creek is approximately 1.6 km (1.0 mile) long and has a moderate gradient (2-4%). Indian Creek is surrounded by ponderosa pine (*Pinus ponderosa*) and juniper, and flows into upper Paulina Creek, north of Paulina, Oregon. BLM fenced 1.6 km (1 mile) of the riparian corridor in 1981-82 and two large springs in 1977. Cattle have not legally grazed the riparian zone since the riparian fence was built, but trespass may have occurred.

In 1978, beavers resided around the upper portion of the survey reach and were damaging aspen (*Populus tremuloides*) clones and an old cottonwood (*Populus trichocarpa*) stand. After the survey, the cottonwood grove was fenced, and individual trees were wrapped with

chicken wire. In 1994 there were no beavers in this section of stream though there was sufficient willow to support them. They were likely trapped out a number of years ago.

The riparian community of Indian Creek is dominated by willow, alder (*Alnus* spp.), and grass, with isolated groves of aspen and cottonwood. Cobble and boulders dominate the substrate for the length of the stream. The canopy of ponderosa pine, willow, and alder provide a moderate to high amount of shade.

ROBA CREEK

The surveyed portion of Roba Creek is approximately 2.6 km (1.6 miles) long and has a moderate gradient (2-4%). Roba Creek neighbors Indian Creek on the east and also flows into upper Paulina Creek. While ponderosa pine and juniper surround both streams, riparian communities are vastly different. Willows, alders, and cottonwoods are rare to non-existent in this part of Roba Creek. Portions of this stream are in poor condition with extensive cutbanks and active erosion.

Two large springs at approximately 1.6 km up the reach were fenced in 1978. Riparian corridor fencing was done in 1983. No grazing has been permitted since that time, but at least one instance of significant trespass was recorded in October of 1991.

Between 1975 and 1978, the area was thinned and slash burned with debris cleaned out of the channel. In-stream structures and juniper rip-rap were installed in 1979 above a road ford. In 1982, structures were modified and strengthened, and rip-rap placed on cutbanks up to the forest boundary. One structure washed out in the winter of 1982-83 and was repaired the following year. Another washed out in 1983-84, and had not been repaired by the following summer. In the 1994 survey, the only portions of the stream that supported sedge-rush communities were immediately upstream of drop structures.

PAULINA CREEK

The surveyed portion of Paulina Creek is approximately 0.4 km (0.25 miles) long. This reach of Paulina Creek is low (<2%) to moderate (2-4%) gradient and feeds directly into the North Fork of Beaver Creek, just northeast of Paulina, Oregon. The substrate is predominantly cobble, with some gravel and sand. This small stretch of stream has a wide active floodplain (approximately 20 m), and a considerable community of willows in the upper portion.

When surveyed in July 1994, cattle were present and shrubs were browsed. Summer use occurs in this allotment occasionally. It is managed in a rest-rotation system with several other pastures and no riparian fencing. Prior to 1987, the stream had been grazed summer, fall, or spring, in alternating years. From 1988 to 1992, cattle grazed in the spring, and were taken out by mid-June. It was rested in 1993. In 1994 grazing was scheduled for mid-June to mid-October.

BRONCO, BEAVERDAM, AND HEISLER CREEKS

The surveyed portions of Bronco Creek were approximately 2 km (1.25 miles) long, Beaverdam Creek 2.4 km (1.5 miles) long, and Heisler Creek 2 km (1.25 miles) long. All three have moderate gradients (2-4%).

These streams are located northeast of Paulina, Oregon, near the Rager Ranger Station. They are higher in elevation than any other streams resurveyed, and are surrounded by ponderosa pine, fir (*Abies* spp.), and juniper forests. All three streams are contained within the Bronco pasture of the Humphrey allotment and are grazed the same. Within a rest-rotation pattern with other pastures, spring grazing has been the management plan for years. However, the Bronco pasture was reported to have been trespass grazed summer season-long for 5 or 6 years, ending in 1991. When the original surveys were done in 1978, the area had been rested for several years.

All three streams have similar topography. Starting from the mouth they are moderate to high gradient with boulder and bedrock substrate. The valleys are narrow and, consequently, so are the riparian zones. Vegetation is quite thick in these areas, and is comprised of an assortment of dogwood (*Cornus stolonifera*), alder, willow, currant (*Ribes* spp.), rose (*Rosa* spp.), mock-orange (*Philadelphis lewisii*), snowberry (*Symphoricarpus* spp.), and occasional aspen and cottonwood. Some of the surrounding ponderosa pine and fir trees, sometimes within the riparian zone, are very large. Roughly 400 m into each of the streams, the gradient is lower and the valley wider. Portions of Bronco and Heisler are quite wide and were called willow-grass meadows in the new survey.

RESULTS AND DISCUSSION

Results are reported for changes in riparian area (Figure 1), bank damage (bare bank) (Figure 2), cutbank length (Figure 3), and community composition. Percent changes in community composition are relative to the base percent composition recorded in the initial survey. For example, if the grass-sedge-rush community composition increased from 24% to 36%, the reported change is 50% increase.

Increases in riparian area and decreases in bank damage and cutbank length are positive indicators of riparian improvement. Within community composition, increases in grass-sedge-rush, shrubs, and litter are positive indicators; and decreases in forbs and bare ground are also positive indicators. Forbs were generally, but not always, upland and weedy species.

BEAR CREEK SECTIONS 1-4 (SECTIONS 1, 3, 4: LATE WINTER/EARLY SPRING GRAZING; SECTION 2: EXCLUSION)

The riparian area in section 1 increased nearly two-fold from 1978 to 1994 (Figure 1). The total bank damage dropped 94% (Figure 2). The largest drop was in natural bank damage. Sedges and rushes dominated the greenline along the stream banks. Litter increased six-fold. The increase in riparian area is very positive, as are the decreases in bank damage and length of cutbanks (Figure 3). The new riparian area is likely a conservative estimate. Deep-rooted clover (*Trifolium* spp.) plants with cheat grass (*Bromus tectorum*) at their bases could be construed as riparian vegetation by some, but were excluded from the area in the recent survey. The increase of litter on the ground suggests timing of grazing that allows subsequent plant growth. Nearly all of the juniper rip-rap has been buried to some extent, some almost entirely, which suggests aggradation occurring in this stretch of stream.

The riparian area in section 2 increased by 60% from 1978 to 1994 (Figure 1). Bank damage was only 9% of what it was in 1978 (Figure 2). The 30 m of bank damage due to livestock in the present survey occurred immediately downstream of the exclosure in a water gap. Sedges and rushes dominated the greenline. Litter increased 10-fold. Immediately upstream of the exclosure is a wide meadow-like section that is difficult to distinguish from the exclosure itself. Beaver dams were common both within and above this reach, often catching sediments before they arrive in the exclosure. For several kilometers upstream, the land management is such that there is little active erosion occurring, curtailing aggradation and riparian expansion. A stand of large willows, present in this section at the time of the previous survey, were mere skeletons in 1994. According to manager observations, an infestation of caterpillars has decimated the willow population in all of Bear Creek for several years.

The total riparian area in section 3 increased 20% (Figure 1). Bank damage decreased from 93 m in 1978 to 70 m in 1994 (Figure 2). The biggest decrease was in the natural bank damage, as it fell from 93 m to 21 m in 16 years. While there was no trampling damage in 1978, 49 m were recorded for 1994 due to the collapse of well-vegetated overhanging banks. No cutbanks were recorded in 1978, but 82 m were reported in 1994 (Figure 3). Part of this length was at the upper end of the section where cattle cross frequently. Another portion of the cutbank length, toward the bottom of the section, was at the toe of the hill slope, and may be due to natural stream movement. The forb component of the vegetation composition dropped 25%, and the grass-sedge-rush component increased 26%. The other components showed only minor variation. As was mentioned above, this section of Bear Creek has changed very little. The bare bank damage (bare bank) was low to begin with, as this stretch has been grazed appropriately since the years before the original survey. The changes in plant composition are indicative of an expanding riparian zone. There are yellow lotus (*Astragalus* spp.) and clover existing beneath a canopy of sagebrush. The change from forbs to grass-sedge-rush has occurred in the old channel community type, where equisetum (*Equisetum* spp.) was being replaced by grasses and drier rushes.

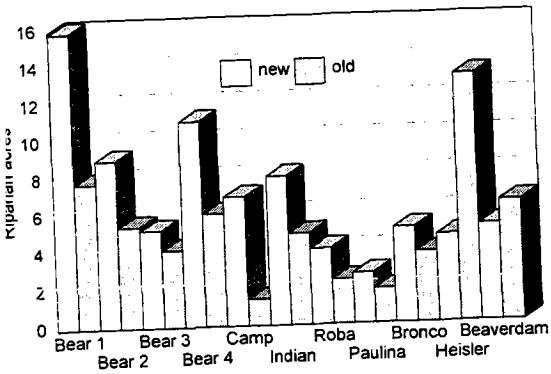
The riparian acres in section 4 increased nearly two-fold from 1978 to 1994 (Figure 1). Bank damage was 609 m in 1978, and was down to 46 m in 1994 (Figure 2). Only 6 m of rip-rap were observed on this stretch of stream. The grass-sedge-rush component of the vegetation increased by 40%, and the forb component dropped by one-third. The activities of beaver have greatly altered this section of stream. In several locations, the floodplain was ringed with dead juniper either drowned-out or chewed by beaver. Several headcuts observed in this stretch may also be due to beavers. After a dam is abandoned and it washes out, the stream headcuts through accumulated sediments, migrating upstream. This downcutting was responsible for some cutbank lengths recorded in 1994 (Figure 3).

CAMP CREEK (CURRENTLY SPRING GRAZED)

The total riparian area of Camp Creek increased nearly five-fold from 1978 to 1994 (Figure 1). A large portion of the area increase is due to sediments captured by the gabions. The total bank damage decreased from 1240 m to 260 m (Figure 2). In the 1988 survey, bank damage was not broken into natural, trampling, and other causes. The length of cutbank decreased by 33% (Figure 3). The gabion-induced communities were still catching large amounts of sediment, and in some places bank vegetation was being inundated. For the 1994 survey, this was considered to be natural bank damage. This section of stream had the tallest eroding banks of any of the others surveyed in 1994. The grass-sedge-rush component increased by one-third. The litter component increased 10-fold. The bare ground component decreased by 60%. As with most of the other sections surveyed, a secondary/old channel community was recorded in 1994 where none was recorded in 1978. This section of stream seemed to be recovering; however, the 1988 bank damage survey, the event in 1986, and the gabions all tend to confuse the question of how much recovery has taken place. The changes in vegetation composition, the diversity of community types, and the presence of secondary channels were positive.

INDIAN CREEK (GRAZING EXCLUDED)

The total riparian area for Indian Creek increased by 60% from 1978 to 1994 (Figure 1). Bank damage in 1994 was only 5% of the original (Figure 2). Cutbank lengths dropped by 83% (Figure 3). The composition of the



igure 1. Summary of riparian area (in acres) per surveyed reach (variable lengths).

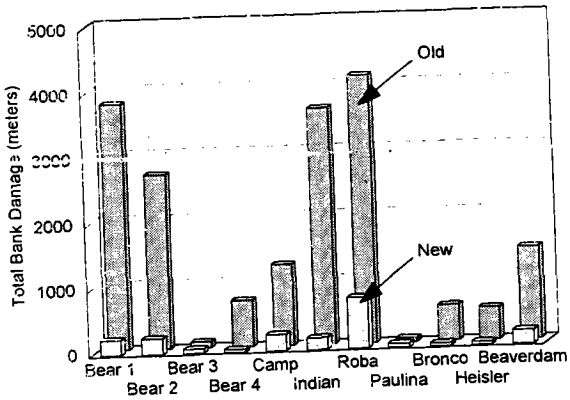


Figure 2. Summary of total bank damage (bare bank in meters per 400 meters stream length).

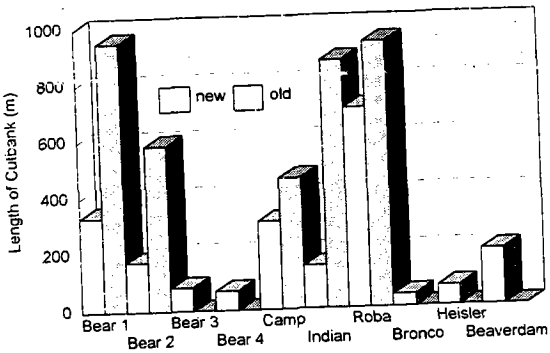


Figure 3. Summary of cutbank length (meters per 400 meters stream length).

riparian zone changed considerably since the original survey. The grass-sedge-rush and litter components more than doubled and bare ground was reduced by half. The percentage of the riparian zone composed of shrubs and trees was recorded as less than one-third of what it had been. Flow was intermittent, as it was in the original survey. Secondary and old channels made up significant portions of the new riparian area, and were not recorded at all in the old survey. In spite of the decrease in percent shrub composition, several species of willows were thriving, as well as other species of woody plants, grasses, and forbs. Sedges and rushes were rare along the stream, but dominated the seeps and springs. After reviewing the photographs from 1978 and comparing them with 1994 photographs, the dramatic drop in shrub composition is suspect. Differing methods of splitting communities and determining the step-toe path are likely the reasons for the decrease. The basal cover is much better now with the increases in the herbaceous and litter components. The cottonwood grove was not doing well. There were no young trees to replace the 20 decadent trees. The aspen stand that was recorded at the same location as the cottonwood stand is reduced to downed wood and one or two trees. These changes were not due to livestock grazing since this was an exclosure.

ROBA CREEK (GRAZING EXCLUDED)

The total riparian area of Roba Creek increased by 66% between the two surveys (Figure 1). While this stream had the highest amount of bank damage reported in 1994 (790 meters), this number is less than 20% of the 1978 reported damage (Figure 2). In the original survey, a large portion of the bank damage was due to logging activities. Cutbank lengths have decreased little over the years (Figure 3).

The channel of Roba Creek consists predominantly of cobble and boulders. In significant portions of the stream length, the channel is composed of sand and gravel. The area of the two springs fenced in 1978 changed little over the 16 years, but the area of all springs and seeps expanded.

The composition of the riparian zone decreased in bare ground by 33% and forbs by 40%, and increased in litter by over 100% and the grass-rush-sedge component by 50%.

In spite of livestock exclusion, portions of this section were still in poor shape. Sediment loads were still quite high, due to the extensive cutbanks, and stream bank vegetation was not of the type effective for maintaining banks. The shade provided by the ponderosa pine canopy in Roba Creek is considerably higher than in Indian Creek. While Indian Creek is in the next drainage over, the soils are much different. The cobble layer that makes up most of Indian Creek is also present in Roba Creek, but it is buried under several feet of much lighter soil. The deciduous community so common in Indian Creek doesn't exist on this section of Roba Creek.

PAULINA CREEK (VARIABLE GRAZING SEASON IN ROTATION WITH OTHER PASTURES)

The total riparian area of Paulina Creek increased by nearly 50% in 16 years (Figure 1). Bank damage (bare bank) was slightly higher than in the previous survey (Figure 2). In the old survey, all of the bank damage was reported as being natural (cutbanks). In the 1994 survey, bank damage was predominantly due to cattle. Natural bank damage recorded was associated with a headcut moving up from the mouth of the stream. No cutbanks were recorded for either survey.

The composition of the vegetation dropped by 25% in the grass-sedge-rush component and increased from 0 to 27% in the litter component. In this 0.4 km reach, the willow community increased from 0.05 ha to 0.6 ha.

BRONCO, BEAVERDAM, AND HEISLER CREEKS (REST-ROTATION SPRING GRAZING)

The riparian area of Bronco Creek increased by approximately one-third from 1978 to 1994 (Figure 1). Total bank damage decreased by a factor of 10 (Figure 2). In the original survey, no cutbank community was recorded, while in the 1994 survey, 42 m were recorded (Figure 3). The grass-sedge-rush component of the riparian vegetation increased by 20%, bare ground increased by 50%, and forbs decreased by nearly 50%.

There were fewer communities found in Beaverdam Creek than either Bronco or Heisler Creeks. Willow, alder, and dogwood were common, and a considerable length of secondary/old channel community was found. The total riparian area was 20% less than it was in 1978 (Figure 1). The spring seep community area expanded dramatically, from 0.01 ha in 1978 to 0.6 ha in 1994 along the 2.4 km reach. The composition of the riparian vegetation changed significantly. The grass-sedge-rush component increased by over 50%, the forbs by 400%, and litter by 80%. The bare ground component decreased by 50%, and shrubs by 66%. Bank damage has decreased by 85% (Figure 2). Bank damage due to logging activities (133 meters) was reported in the original survey. Cutbanks in this stream were the most severe of the three, with almost 200 m in 1994, and none recorded before (Figure 3).

Although the riparian area of this section of Beaverdam Creek had not changed dramatically since 1978, the increase in cutbanks, the loss of beaver, and the variations in the riparian community suggest that this stream has been set back in condition. During the August 1994 survey, the shrubs were in good condition, but the herbaceous cover was cropped very closely.

The total riparian area of Heisler Creek decreased by two-thirds from 1978 to 1994 (Figure 1). In the old surveys, groves of choke-cherry (*Prunus virginiana*) and cottonwood were recorded. In the new survey, the groves were located, but they were no longer part of the riparian zone. Bank damage decreased by 90% (Figure 2), while the length of cutbank community increased from zero to 69 m (Figure 3). Over 100 m of the original (1978) bank damage was due to logging activity.

The fewer number of community types found in 1994 compared to 1978 may be attributed to an increase in the number of willows which serve to merge community types. The spring-seep and secondary/old channel communities were significant portions of the total riparian area in 1994, and were not recorded in the 1978 survey. The drastic drop in area may be related to the loss of beaver, incision into portions of the floodplain, and a very dry summer. Several wide portions of the valley bottom were high and dry, with recent cutbanks at the stream's edge. The 84% decrease in shrub composition is suspect based on the old photographs. Depending on where the composition hits were taken with respect to the stream length, and the location of the step-toe path with respect to the riparian width, compositions can be quite variable.

Although all three of these streams were reported to have been trespass grazed during the summer for a few years, Bronco Creek was able to maintain itself while the other two deteriorated. The maintenance of the beaver population in Bronco Creek may have been a factor.

MANAGEMENT IMPLICATIONS

Even with the wide array of grazing strategies, topography, and communities, most of these streams appear to be in better condition now than they were in the late 1970s. Riparian conditions and function improved in reaches with an appropriate grazing management as well as in those excluded from livestock. In Heisler and Beaverdam, the two streams that decreased in area, the allotment did not have compliance to the grazing plan for at least some of the 16 years since the original survey.

The diversity of responses to appropriate grazing and livestock exclusion serves to illustrate the point that all of these streams are functioning in ways that are unique. Factors such as climate, landscape setting, soils, and land use history all make a difference and must be factored into determination of an appropriate grazing management prescription. Although sample sizes were too small for rigorous statistical comparisons in this study, differences in stream gradient, sediment loading, and beaver activity (can be positive where site conditions promote active, stable dams) appeared to influence rate of improvement in riparian zones. Differences in rate of improvement could not be detected between reaches with an appropriate grazing management and those under exclusion. Exclusion for a period of time might be helpful to jump start a recovery process in some situations; however, that too is site specific and must be considered on a site-specific basis.

Results from this study and from observations of numerous grazing management prescriptions throughout the West suggest that timing of grazing may be the most important factor in developing an appropriate grazing prescription for riparian areas. Grazing can generally be compatible with improving deteriorated riparian conditions and maintaining those functioning properly. The key is an appropriate grazing prescription, which must be site and situation specific, and adherence to that prescription.

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REASONABLE MANAGEMENT CHANGES TO IMPROVE WATER QUALITY AND QUANTITY

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ABSTRACT

Oregon has launched a concerted effort to improve water quality and restore fisheries that have declined over past decades. Water quality criteria have been reviewed and an historically high number of stream segments identified as not meeting the criteria. In response to this effort there has evolved a partnership of regulatory agencies, research organizations, and the environmentally sensitive Oregon population to change those management practices that are perceived as damaging to water quality and to initiate alternate practices that protect and enhance water quality.

Although there is an immediate and ongoing need for greater understanding of natural ecological processes, the current need is really one of action. Environmentally sensitive land and livestock management practices are generally well known and available for implementation. From a prescriptive position, the goals are to prevent the entry of excessive sediment, organic matter, and toxic materials into streams, lakes, and groundwater aquifers; to maintain summertime flows as large as possible based upon the hydrology of the area; and to provide vegetative shelter to the streams to avoid excessive radiant heating.

Utilize natural processes along stream corridors to buffer the stream from potentially damaging human activity. Expressed alternately, this means that we protect riparian zones so they function as biologically active transition zones. For crop producers, this means backing away from the stream sufficiently to protect this area. For grazing managers, this means that we protect that crucial area so it can stabilize stream dimensions, provide water storage, and trap particles that would otherwise invade the stream. Residential landowners also have an opportunity to protect water quality by avoiding the temptation to plant monocultural, heavily fertilized, herbicide-managed lawns down to the water's edge. Timber managers have an opportunity to minimize road construction, control grades to reduce erosion, protect riparian strips and construct stream crossings that are sensitive to the environmental needs of the area. Nature has a wonderful way of incorporating diversity into natural riparian areas that we are only still discovering. Urban planners and taxpayers also have an opportunity to protect riparian areas by avoiding waterline development, paving to the waterline, and constructing sidewalks and parking lots in the riparian zone; all have contributed to our loss of these natural stream protection buffers.

Groundwater and surface water are interrelated to the extent that we must regard them as a single resource. There has been a tendency to regard surface and groundwater as two separate resources independent of each other. As researchers have tried to understand the hydrology of water quality limited streams in Oregon, it has become increasingly clear that especially low flow stream water quality ranging from temperature to nitrate content is dependent on groundwater influences. In Oregon, most of the streams for which we have water quality concerns arise within the state and depend on our management decisions. Thus, watersheds have become the focus of much of our current activity. These watershed management plans, when properly conceived, are responsive to both surface and groundwater concerns.

Watersheds not only collect precipitation and transport that precipitation to the stream system, but they are the storage system that determines when the water flows on the surface. August streamflow depends on having precipitation that fell last winter arrive in the stream system during August. In our desires to more quickly divert winter precipitation away from our driveways and off our paved streets, we preclude that water from being part of the summertime resource; instead it adds to the winter excess flow.

Topsoil is a biologically active mass that moderates the interface between human activity and the hydrologic processes that are crucial to our water quality concerns. Whether we are managing our front lawn, a grazed pasture, an orchard, an irrigated field, or a forested hillside, the soil of that area provides the interface that is crucial to protecting water quality. That soil has demonstrated a great ability to serve our welfare so long as we

make reasonable demands. All of us who have functioning septic tank systems appreciate the ability of soil systems to accept pollutant-laden waters and purify them sufficiently so they can be reused. Crop producers similarly depend upon the soil system to store and release both water and nutrients at the appropriate time to make commercial production possible. When we are at our best and recognize the limitations of the system, the system serves us well.

As persons interested and concerned about water quality and the future of the Northwest, these understandings of natural systems have been translated into best management practices (BMPs). Those practices have contributed to our progress in water quality restoration and will continue to be important as we move forward.

BMPS FOR NON-IRRIGATED CROP PRODUCTION

- Leave a vegetated strip between tilled area and adjacent streams
- Practice the established erosion control procedures
- Utilize nutrient management techniques to match application to crop needs and avoid application of excess fertilizers
- Adopt reduced or minimum tillage practices to provide maximum protection and reduce the exposed soil

BMPS FOR IRRIGATED CROP PRODUCTION

- Water application rate matches the soil infiltration rate
- Nutrient management matches crop needs and avoids excess being applied
- Water applied in response to plant use to avoid moving fertilizer beyond the root zone
- Practice of established erosion control procedures
- Protect soil surface from winter wind and rain
- Establish a scavenger crop to recover nutrients that may have been left in the soil profile
- Leave a vegetated strip between tilled area and adjacent streams
- BPMs for grazing livestock operations
- Divide pasture areas appropriate to the area to get maximum productivity
- Protect riparian area soil structure to avoid bank deterioration and stream spreading
- Utilize supplemental watering and feeding locations that promote use of the entire pasture and avoid cattle over using riparian areas
- Protect riparian area vegetation by controlling animal intensity
- Select and maintain grass in productive condition
- Manage animals so the pasture is appropriately grazed in response to the season and amount of forage available

BMPS FOR SMALL LIVESTOCK OPERATIONS

- Manage pasture areas to maintain an effective grass cover to prevent erosion
- Locate watering devices, shade, and supplemental feed sources to encourage use of the entire pasture area and prevent riparian zone damage
- Collect and disperse runoff from holding areas and other manure-covered surfaces devoid of vegetation
- Cover manure piles to prevent leaching of soluble nutrients
- Compost accumulated manure to achieve higher valued product
- Grade pasture and confinement areas to provide greatest opportunity for surface vegetation to trap particles and microorganisms

BMPS FOR URBAN HOUSEHOLDS

- Remember that storm sewers are direct conduits to streams:
  - Avoid spilling fertilizers and pecticides on sidewalks and streets
  - Never pour used oil or other hazardous materials in the street or down the storm sewer
  - Wash your car, lawn mower, and other equipment in the grassed areas rather than in the drive to prevent direct discharge to the stream
- Apply lawn fertilizers and pest control materials in the smallest quantities necessary to achieve your goals
- Water the lawn and decorative plantings in response to their water use to avoid losing your fertilizer to the groundwater
- Dispose of left-over pesticides, paint, solvents, and other toxic materials in an approved hazardous materials disposal facility
- Consider the selection of more drought-tolerant plantings to save and protect water
- Avoid destruction of streamside trees, shrubs, and wild vegetation. Riparian areas best function as wild areas

WATER QUALITY MONITORING ASSOCIATED WITH COMMUNITY PASTURE DEVELOPMENT IN SOUTHEASTERN BRITISH COLUMBIA

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ABSTRACT

In 1982, a Community Pasture was proposed for the McMurdo Bench area south of Golden, British Columbia. Development of the pasture consisted of converting 300 ha. of Douglas-fir/lodgepole pine forest to an orchard-grass/alfalfa mix for cattle grazing. By 1992 the timber removal was complete and seeding began on eight pasture units making up the community pasture. During the development period there was extreme public opposition to the project because six creeks drained through or originated on the pasture units. These creeks have 33 domestic water users including a public school and restaurant/store. Their concerns were degradation of water quality through logging practices, changes in streamflow as a result of timber removal, contamination of water from livestock, and mitigation should contamination occur. To address these concerns, the B.C. Ministries of Forests, Health, Agriculture and Environment, the Cattleman's Association, and the water users developed a plan and pasture design that would ensure a level of water protection. To assist in evaluating the effectiveness of this plan a water monitoring program was initiated. Sampling began in 1992 subsequent to forest removal but prior to conversion to grasses and cattle grazing. The study design was to sample above and below the pasture units with one creek singled out for bimonthly sampling on an annual basis. Results to date indicate that minimal changes in water quality have occurred. These results are extremely useful in reducing the concerns of water users.

Key words: water quality, nutrients, coliform, water sampling, livestock grazing, community pasture

INTRODUCTION

One of the more contentious issues in livestock management on Crown-managed range areas in British Columbia is contamination of downstream water supplies used for domestic purposes. Every summer, "boil only" water advisories are issued to numerous communities whose water supplies are considered by the B.C. Ministry of Health to be contaminated. Where livestock are located in the "contaminated" watershed, they are often singled out to be the cause of the pollution although there are other factors which could contribute to the contamination.

In 1982, a 300 ha. community pasture for cattle grazing was proposed by a group of local ranchers on benchland above Parson, British Columbia. The proposal was put forward because of a lack of Crown range and availability of government funding assistance. At the time there was opposition to the proposal by local residents, and the Forest Service was concerned about taking Crown land out of the forest base. In the end, the decision to go ahead with the proposal was made at the political level.

The McMurdo Bench is considered a prime timber growing site with mixed stands of Douglas-fir, lodgepole pine and western larch. Eight separate pastures were to be cleared, stumped, raked and fenced before being seeded to an orchardgrass/alfalfa mix. The pastures would be grazed between mid-May and late September on a rotational basis. The public was consulted on the proposal, and one of the main issues to emerge was the potential effect on water quality. Under the proposal, the pastures would cover an area which had six creeks flowing through it. These creeks were domestic water sources for 33 water licenses including the local public school and a store/ restaurant.

To provide a vehicle for public input into the process and dispersion of information, a McMurdo Bench Co-ordinated Resource Management Plan (CRMP) area was officially designated in December 1983. In addition, to address the main concern for water quality, a water resources subcommittee was formed in October 1984. The

committee consisted of government representatives, water users and ranchers who spent 1 year working out the details for converting the forest to community pastures. The four objectives of the committee were to:

1. Conduct analysis of the water resource
2. Propose appropriate water management constraints and conditions to resource activity in the CRMP area
3. Identify roles and responsibilities of resource users in each of the domestic watersheds
4. Develop a contingency plan in the event of impairment to water supply

Annual CRMP meetings were held as well as field tours to update interested stake holders and receive feedback on the pasture development.

Most of the water quality protection measures employed on the McMurdo Bench pastures are more intensive than those commonly used in domestic watersheds throughout B.C. Some of the measures for livestock management were fencing out all access to creeks and ensuring a minimum 20 meter vegetation buffer strip was retained on creeks adjacent to pastures. Water for livestock was to be gravity fed into dugouts or troughs. Any area within a pasture that sloped towards a creek and had the potential for overland flow, was ditched or regraded to prevent water from entering the creek. In some instances, intermittent tributaries were fenced as well as any wet areas within pastures. No herbicides or pesticides were allowed on the pastures. A bond was to be posted yearly by the Grazing Association for mitigation should they be found negligent in their livestock management. Mitigation would include costs to cover repair of stream restoration or provide potable water in the case of disruption.

Part of the challenge when dealing with public groups (water users) is their lack of understanding on how livestock management and pasture maintenance may affect water quality. Often times individuals within the group make outrageous claims based on limited studies which in some cases reflect worst case scenarios. These inflammatory statements tend to divert attention from the actual situation and make compromise more difficult. Without background water quality data on which to base decisions, the whole group often assumes the worst with respect to impacts on their water supply.

During the 1992 annual CRMP meeting it was suggested that a water quality monitoring program may assist in understanding the livestock-water quality issue by providing local data. It was pointed out that most of the potential impacts may have occurred as a result of the forest being converted to pastures, but with livestock still to be grazed on the new pastures, additional information would be obtained.

The purpose of this paper is to report on the water quality sampling program initiated in response to public concerns over the effects of livestock grazing in domestic water supplies and report on the effectiveness of such a program in dealing with water quality concerns.

STUDY LOCATION AND METHODS

The McMurdo Benches community pasture is located 42 km south of Golden, British Columbia near Parsons and consists of eight separate pastures (Figure 1). For the most part, each of the pasture boundaries is defined by various streams draining through and over the McMurdo Bench area.

The water quality monitoring strategy was dictated to a large extent by available funding for laboratory analysis. The committee decided, after reconnaissance of all the pastures, to sample one representative stream and carry out biannual spot samples on three other streams. Paddy Creek was chosen as the representative stream as it has pastures on either side of it, is accessible year round for sampling, is the most heavily licensed stream for domestic water use, and has a local observer willing to take the samples. In addition, cattle grazing had already been initiated on some of the pastures, so it was important to use a stream where we would be able to gather sufficient water quality data to provide an index prior to cattle use. The other streams spot sampled were: Monteagle, Hogranch, and Beards. A cause-and-effect sampling program as described by Ponce (1980) was established on the four creeks. Permanent sampling sites were located above and below the pastures on each of the creeks. Sampling for all parameters was carried out monthly with sampling for coliforms occurring biweekly. Occasionally extra samples were taken during snowmelt periods and heavy rains. Additionally, samples were taken during an aerial fertilization program to provide spot measures of water quality during and following the application.

Paddy Creek is formed by water draining off the upland slopes and water emerging from groundwater within Paddy pasture. During the spring snowmelt, overland flow is evident in some places on the pasture. The estimated catchment area above the upper site at an elevation of 1,030 meters is 176 hectares. The area above the lower site at an elevation of 970 meters is 244 hectares. The catchment raises to an elevation of 2,200 meters. Paddy Creek exhibits the typical snowmelt-dominated runoff pattern typical of southeastern B.C. with the peak flow occurring in May to early June. Estimated flows in Paddy Creek based on a gauged station nearby are as high as .320 m^3/sec to a low of 0.17 m^3/sec. The distance separating the upper and lower sampling sites is approximately 950 meters. Although the upper and lower sampling locations have defined stream channels, the creek meanders through some low-gradient, swampy area

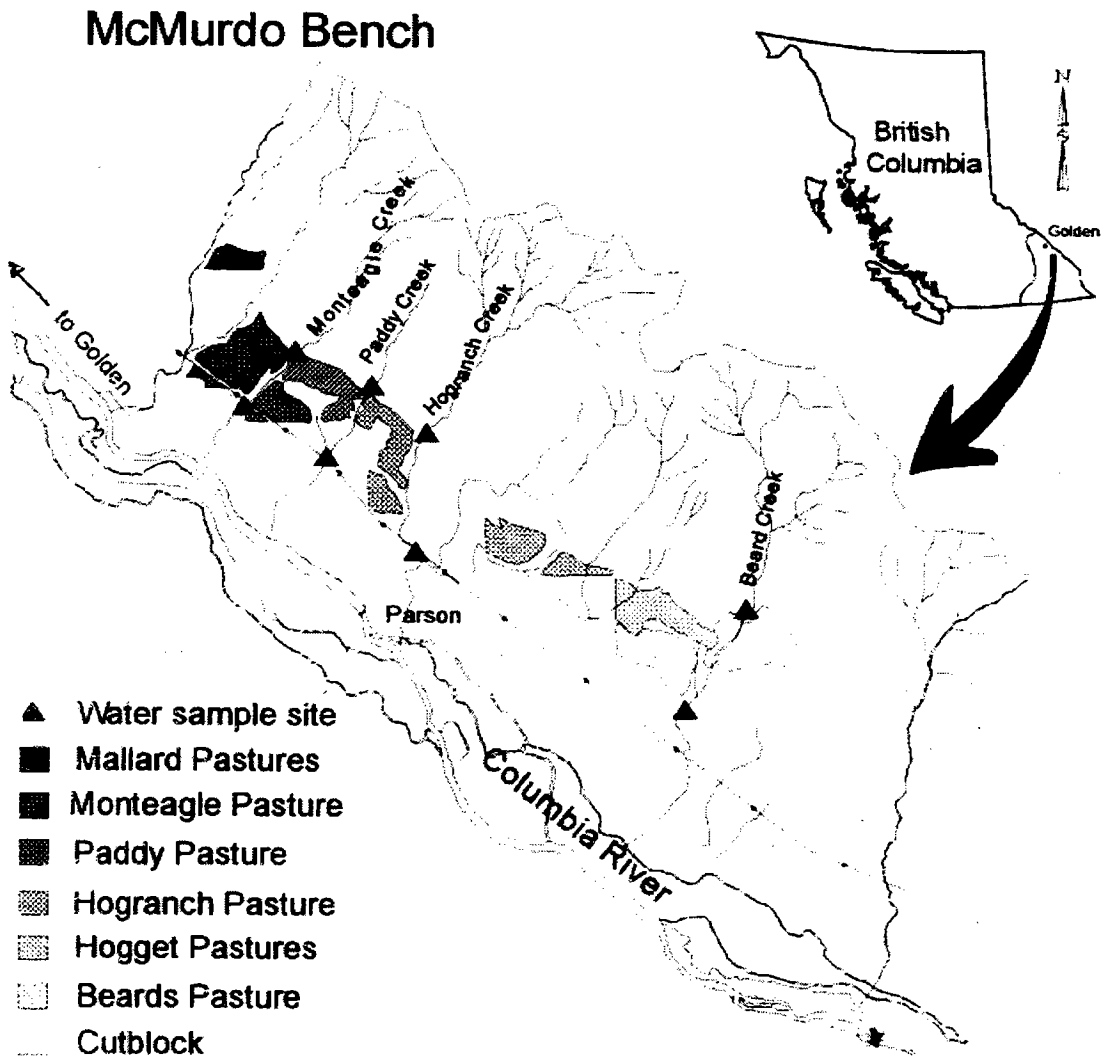

Figure 1. Location of the pastures on McMurdo Bench in southeastern British Columbia.

with an indistinct stream channel. Paddy Creek also receives a small amount of groundwater emerging from Hogranch Pasture, and hence this pasture exerts an influence on the hydrology of Paddy Creek. Hogranch Creek to the southeast also has a control gate on it to divert some flow into Paddy Creek to augment volume as needed during the low flow period. Soils on the two pastures are medium to fine textured regosols. Several soil series exist in the area with the majority being of a sandy loam texture derived from calcareous alluvial fans. Under natural conditions the soils are well drained.

Water sampling was for the most part carried out by a local resident, who had been instructed in the "grab" method. Samples for general water quality were taken in 2-litre plastic bottles and those for coliforms in 250 ml plastic bottles. All bottles were supplied by the analytical lab. Samples were shipped in coolers packed with ice on the same day of sampling and were in the analytical lab within 24 hours. Analysis was completed at Phillips laboratory in Vancouver. All procedures followed the standard methods and are listed in Gluns and Toews (1989).

The decision on what water quality parameters to monitor was based on what might be expected to change as a result of livestock management as well as the need for general water quality data for the area. The parameters monitored were : Nitrogen—Ammonia, Nitrate plus Nitrite, Organic, and Total; Phosphorus—dissolved and total; Hardness—calcium and magnesium; Conductivity; Turbidity; Coliforms—fecal and total.

Streamflow information was beyond the scope and budget of the study and was not collected although we

realized the importance in interpreting water quality. As no climate station operates in the vicinity of McMurdo Bench, we have used monthly data from Golden, a climate station 42 km to the northeast, to represent total precipitation inputs.

Data analysis consisted of pairing the stations, upper and lower, and developing a relationship between the two. Differences following the period of grazing were then compared to differences prior to the period to provide an indication of possible change. Time series plots provided a visual analysis of the entire water quality record. Water quality before and after livestock were introduced was compared at the upper site of Paddy Creek to ascertain if there was naturally occurring change during the monitoring period.

RESULTS AND DISCUSSION

Water sampling was initiated on September 10, 1992. Although cattle grazing commenced on McMurdo Bench in 1991 in Beards and Little Hogget pasture, cattle did not use Hogranch and Paddy pastures until August 16 and September 11, 1995 respectively. This provided the definable break for the data set into pregrazing ("pre-period") and postgrazing ("post-period").

Average annual (July-June) precipitation inputs as indexed by the station in Golden showed 416 mm occurred prior to grazing and 557 mm during the period of grazing. The higher post-period precipitation was influenced by above average monthly precipitation of 154 mm in November 1995. The 1961-90 climatic normal for total precipitation at Golden is 491 mm. This higher post-period precipitation would have an influence on the hydrology of the streams.

The number of cattle and the period of grazing for each pasture is provided in Table 1. To increase forage production, an aerial fertilizer application was made on June 1, 1996. Approximately 100kg/ha of 35-0-0-10 was applied to all pastures. The pre-period provided approximately 3 years of water samples prior to livestock grazing. The mean concentration for each parameter monitored for the 3 years prior to livestock on the pastures and for the 2-year period following is presented in Table 2. This is put into perspective with the mean values obtained on the other streams monitored on the McMurdo area (Table 3).

The relationship between upstream and downstream sites for the pregrazing period varied with each parameter and were not well correlated. In southeastern B.C. we generally find a good relationship to exist between upper and lower sites on the same stream. Part of the inconsistent relationship between sites may be attributable to the effects of forest removal on the various parameters monitored. This could be a water quality change as well as a water quantity change. Conversion from forest to pasture would have an effect on available groundwater. Greater inflow of groundwater than usual would result in higher concentrations of some parameters entering the stream. This would be especially true during the period of pasture snowmelt. Numerous studies have demonstrated that forest removal can have an effect on water quality and quantity. A review of these effects is summarized by Binkley and Brown (1993) and MacDonald et al. (1991). Since forest removal had taken place prior to the initiation of the sampling period, we assumed that these effects would be incorporated into the upstream-downstream differences.

We did find the mean water quality for all parameters at the upper site was not significantly different between the pre- and post-grazing period for Paddy Creek. This indicates that the quality of water reaching the pastures remained consistent throughout the study period and that any change in water quality at the lower site was not a reflection of changes in water quality between pre- and post-periods.

Overall, changes in water chemistry as a result of flowing through the pastures appeared in some of the parameter concentrations; however, these were not significant given the level of sampling. Results for each parameter measured follows.

Table 1. Summary of the livestock on Paddy and Hogranch pastures during the water sampling period.

Year	Pasture	Stock Class & No.	Dates	AUM's
1995	Hogranch	170 c/c 6 bulls	Aug. 16 - Sept. 10	182
	Paddy	170 c/c 6 bulls	Sept. 11 - Sept. 25	105
1996	Hogranch	170 c/c 6 bulls	June 7 - June 18	84
	Paddy	170 c/c 6 bulls	June 19 - June 27	63
	Hogranch	170 c/c 6 bulls	Sept. 11 - Sept. 20	70
	Paddy	170 c/c 6 bulls	Sept. 21 - Sept. 24	28
1997	Hogranch	170 c/c 6 bulls	June 2 - June 15	98

Table 2. Mean concentration (standard deviation) for each water quality parameter monitored on Paddy Creek.

Water Quality Parameter[1]	Pregrazing[2]		Postgrazing[3]	
	Upper	Lower	Upper	Lower
Nitrogen: Ammonia	.006 (.004)	.007 (.004)	.008 (.011)	.008 (.011)
Nitrogen: Organic	0.09 (.06)	0.12 (.08)	0.09 (.09)	0.14 (.07)
Nitrogen: Nitrate plus Nitrite	.04(.02)	.06 (.03)	.06 (.04)	.03 (.03)
Nitrogen: Total	0.13 (.06)	0.17 (.08)	0.15 (.09)	0.17 (.07)
Phosphorus: Dissolved	.004 (.001)	.005 (.005)	.004 (.002)	.005 (.004)
Phosphorus: Total	.006 (.007)	.006 (.006)	.006 (.005)	.012 (.03)
Hardness	182 (17)	205 (19)	172 (21)	226 (21)
Calcium	43.3 (4.1)	50.6 (4.8)	40.4 (5.0)	54.9 (5.5)
Magnesium	18.0 (1.8)	19.2 (1.9)	17.3 (2.2)	21.5 (1.9)
Specific Conductance	316 (28)	352 (25)	302 (35)	388 (31)
Turbidity	0.3 (0.2)	0.5 (.4)	1.1 (2.3)	1.2 (2.9)

[1] all values in mg/L except specific conductance (uS/cm) and turbidity (NTU).
[2] sample size = 41
[3] sample size = 24

NITROGEN

Nitrogen is present in the water in various forms—nitrate, nitrite, ammonia, and organic. All forms have the potential to be influenced by livestock waste or addition of fertilizers. Total nitrate plus nitrite is recommended by Bauer and Burton (1993) as a nutrient to measure when evaluating water quality effects of grazing. In B.C., we have found that separated out, nitrite is rarely present above detection levels. Twenty-four percent of the Nitrate-Nitrogen samples taken were non detectable. Nitrogen response at upper and lower sites for the entire period is typified by the time series plot for total nitrogen, which is a calculation of ammonia, organic nitrogen, and nitrate-nitrite nitrogen (Figure 2). For the most part, values were higher below the pasture than above for the entire sampling period; however, there were sample dates where values were reversed. These trends were apparent for all forms of nitrogen when individually investigated and there appeared to be no change in nitrogen concentrations during the postgrazing period. Since forms of nitrogen are readily available for biological uptake and chemical transformations, we may account for some of the differences observed between the upper and lower sites by the type of water system in which the nutrient has travelled. The lower gradient of the central part of the stream between upper and lower sampling sites presents an opportunity for nitrogen additions and deletions. In addition, more water is being collected in the system and we could have a dilution effect. We noted that during a spot sample of surface water on Mallard pasture immediately following the aerial fertilization, we measured total nitrogen at 47.3 mg/L. Where the water drained into Monteagle Creek, the level had fallen to 0.23 mg/L. Dilution by the creek played an important role in the lower concentration. Mean concentration for Paddy Creek at the lower site for the postgrazing period was 0.17 mg/L.

PHOSPHORUS

Total phosphorus is another nutrient recommended by Bauer and Burton (1993) when evaluating grazing impacts. In southeastern B.C., phosphorus is a limiting nutrient and any addition often results in algae blooms and a deterioration of water quality. Time series plot for total phosphorus illustrates the variability between upstream and downstream sites (Figure 3). Overall the lower site exhibited a slightly higher mean value; however, an extreme measure (0.151 mg/ L) made on 17 June 1997 was beyond the range of anything previously measured and influenced the mean. Of the 131 samples of total phosphorus taken, 37% of the samples were non-detectable. Dissolved phosphorus exhibited a pattern similar to total phosphorus with several seasonal spikes both pre- and post-grazing. As with the various forms of nitrogen, both measures of phosphorus did not exhibit a change over the period of monitoring.

HARDNESS, CALCIUM, MAGNESIUM

Hardness—a measure of calcium and magnesium—is presented in two period average time series (Figure 4). Visually there appeared to be an increasing trend in this parameter in the postgrazing period. When we investigated this period with respect to what we would expect based on the pregrazing period, we found most of the samples were in fact higher (Figure 5). Both dissolved calcium and magnesium responded similarly.

Table 3. Mean concentration of each of the water quality parameters monitored on four streams on the McMurdo Bench.

Water Quality Parameter[1]	Monteagle		Paddy[2]		Hogranch		Beards	
	Upper[3]	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Nitrogen: Ammonia	0.008	0.005	0.006	0.008	0.006	0.006	0.006	0.005
Nitrogen: Organic	0.10	0.18	0.08	0.15	0.06	0.08	0.10	0.09
Nitrogen: Nitrate plus Nitrite	0.05	0.05	0.05	0.07	0.11	0.12	0.18	0.17
Nitrogen: Total	0.15	0.22	0.14	0.20	0.17	0.20	0.27	0.25
Phosphorus: Dissolved	0.004	0.005	0.003	0.004	0.005	0.005	0.004	0.004
Phosphorus: Total	0.009	0.013	0.007	0.009	0.013	0.029	0.034	0.048
Hardness	170	190	180	213	169	171	180	207
Calcium	39.2	45.0	42.7	51.8	41.2	41.7	39.7	46.6
Magnesium	17.5	19.5	17.5	19.7	16.1	16.3	19.6	21.9
Specific Conductance	300	347	321	376	277	298	319	360
Turbidity	0.7	1.3	0.6	0.9	3.8	11.8	10.8	13.5

[1] all values in mg/L except specific conductance (uS/cm) and turbidity (NTU).

[2] values based on the same sample date as other streams

[3] sample size = 9.

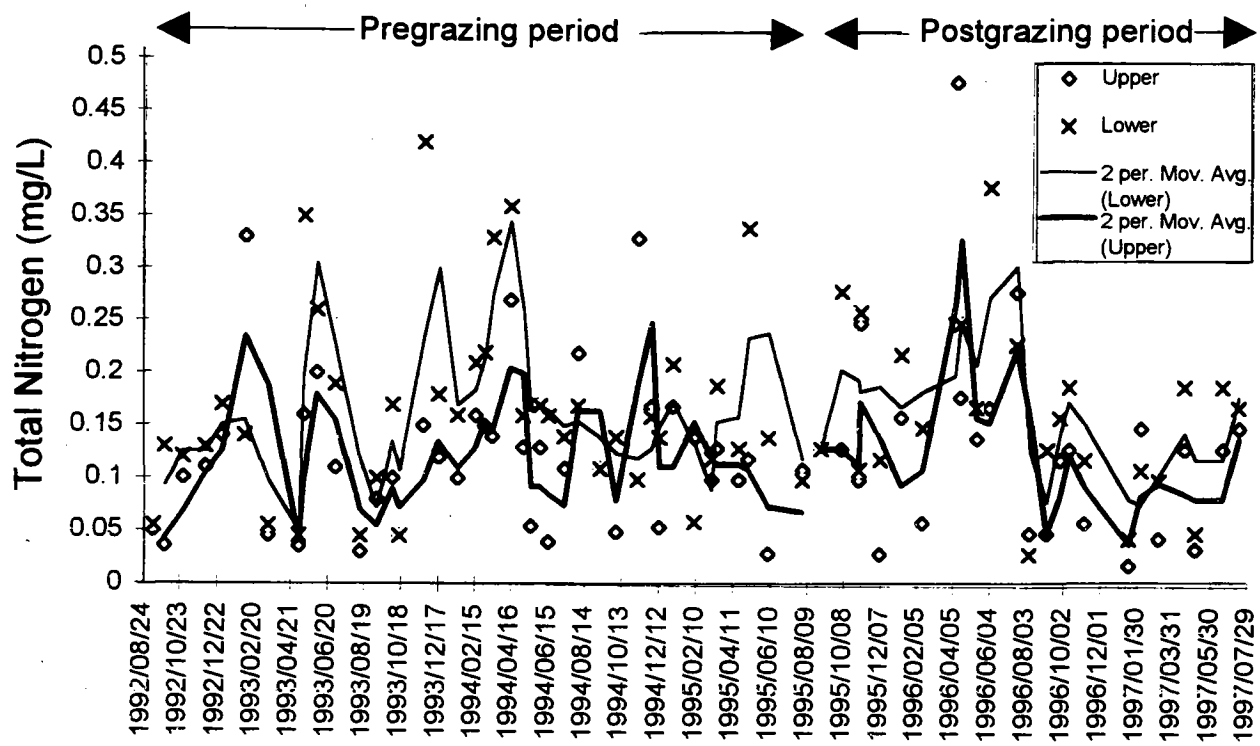

Figure 2. Time series plot for total nitrogen concentrations in Paddy Creek during the sampling period.

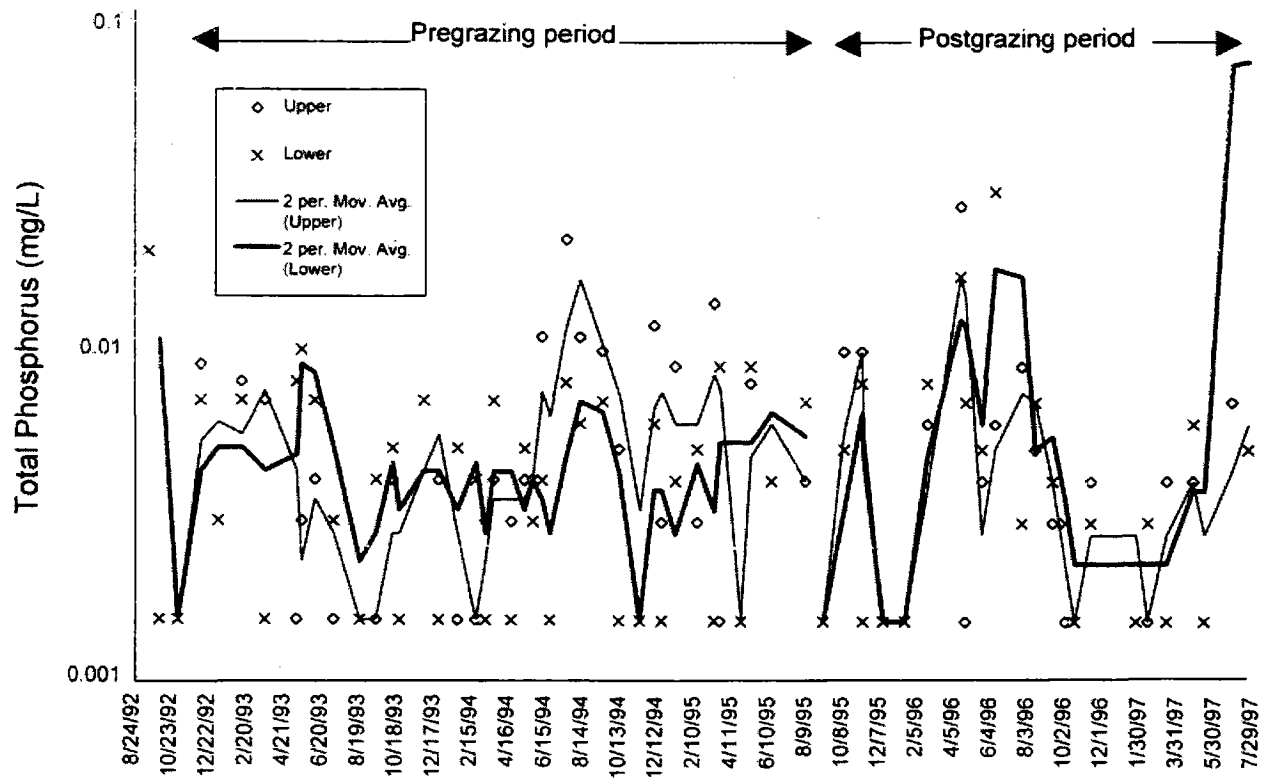

Figure 3. Time series plot for total phosphorus concentrations in Paddy Creek during the sampling period.

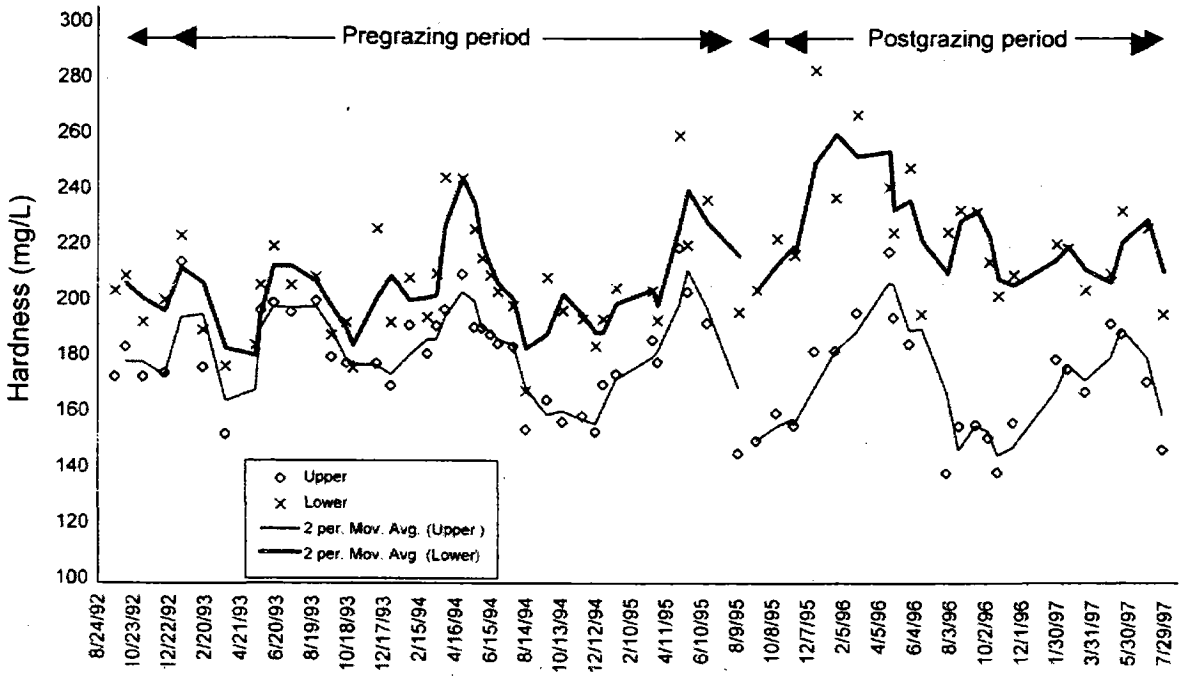

Figure 4. Time series plot for total hardness values in Paddy Creek during the sampling period.

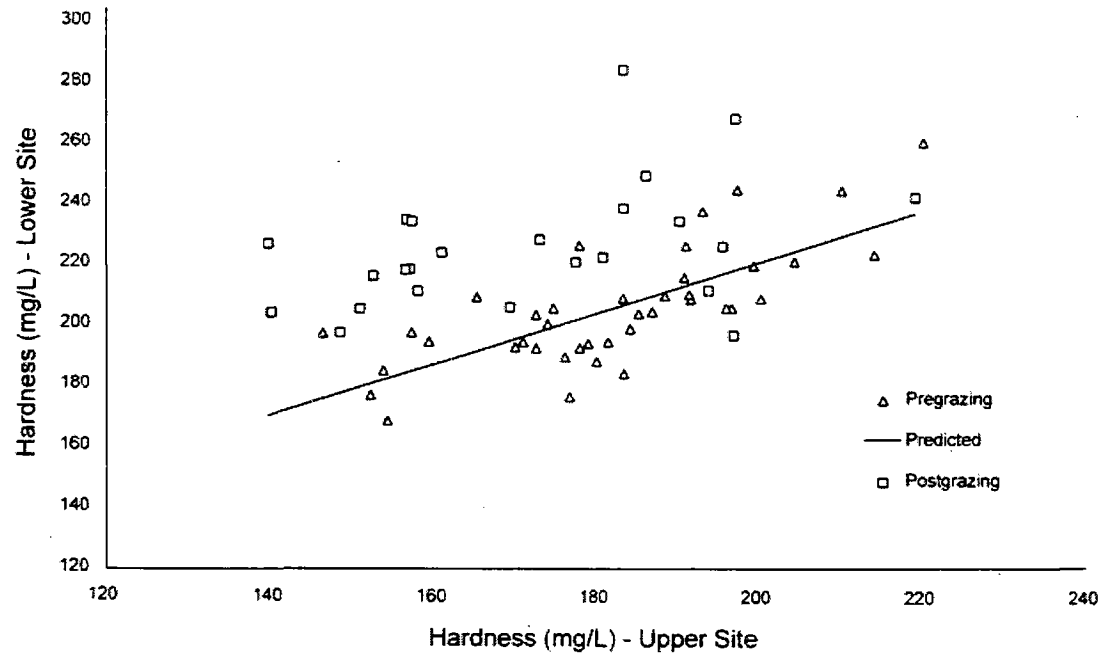

Figure 5. Prediction plot for total hardness values based on pregrazing relationship between upper and lower sites on Paddy Creek.

Very little has been reported with respect to grazing impacts and changes in hardness as reflected in changes in Ca and Mg. The current levels of hardness are bordering on the poor level as suggested in British Columbia Drinking Water Quality Standards (1982). If so, there is a need to understand why this parameter may be exhibiting an increase over the past 2 years. When we compared periods of precipitation, it was found that the postgrazing period was wetter than the pregrazing period and it can be assumed that runoff was proportionally higher. With a greater amount of precipitation there may be a greater amount of calcium and magnesium movement from the area. It has been suggested that as soon as an area with calcareous soils in logged and stumped, the soil disturbance is enough to increase measured calcium carbonate (Kishchuk 1996). This increase in calcium would potentially be available for movement.

SPECIFIC CONDUCTANCE

Conductivity can be used as an index to the number of dissolved ions in the water and hence an index to any change in the ions (Hem 1970). It is particularly sensitive to variations in dissolved solids but provides no indication of the relative quantities of the various components. (McNeeley et al. 1979). Our conductivity monitoring shows a slight increase as viewed in the time series plot (Figure 6) and in the prediction plot of upper and lower sites (Figure 7). This increase could be in part a reflection of increased groundwater contribution to surface flow rather than any effect livestock could have. Although the forest harvesting on Paddy and Hogranch pastures occurred just prior to the onset of sampling, the effects on water quality of timber removal and converting the vegetation to a grass mixture can be showing up during the grazing period. Johnson et al. (1978) also noted an increase in conductivity following a period of grazing. They attributed the increase to the possibility of livestock waste products reaching the stream following rain events. Our higher values are more likely a reflection of the change in hardness due to calcium. Conductivity and hardness are related, and changes seen in one are often seen in the other.

TURBIDITY

Turbidity is shown to be slightly higher at the lower sampling site than the upper site (Figure 8) but within accepted standards with one exception. The one sample exhibiting high turbidity at the lower site is mirrored with a high sample at the upper site. These samples were taken during the annual snowmelt period and we would be hard pressed to relate the difference to cattle use. The low values as related to livestock use of the area are expected during this monitoring program because the riparian zones excluded cattle. Several studies have reported on cattle impacts on streambanks resulting in increased sedimentation and turbidity (Binkley and Brown, 1993). This occurs mostly where cattle have free access to the riparian environment. Cattle were specifically fenced out of stream zones to prevent this problem.

BACTERIOLOGICAL

One of the major water quality measures during any evaluation of the impacts of livestock grazing is bacteriological, although its use has been questioned by Bohn and Buckhouse (1985) when it comes to evaluating wildland streams. Bacterial indicators—total coliforms and fecal coliforms—were monitored as part of this study because they are used by the B.C. Ministry of Health to assess drinking water. Fecal coliform is an indicator of fecal contamination from warm-blooded animals. These bacteria provide a method for detecting the entry of livestock wastes into surface water (Bauer and Burton 1993). Total coliform is used as an indication of relative amounts of bacteria in the water system. We found that both coliform groups exhibited wide fluctuations over the period of water sampling. This fluctuation is not surprising considering that fecal coliforms cannot be separated out as to what the source animal is. Wildlife make use of the pastures for grazing and unlike cows, are not confined by fencing. Wildlife also make extensive use of the riparian areas and were observed in these zones frequently. It may be argued that by creating the pastures for livestock, there is an increase in the use of the area by wildlife. If so, this has not resulted in a degradation of the water as indexed by coliforms. By measuring coliforms at our upper site we were able to get an idea of what the natural fluctuations of the coliform numbers are for the area. We did note that on several occasions, fecal and total coliforms did not meet raw drinking water standards, and that Ministry of Health officials would have indicated that a "boil only" order be placed on the consumption of water. As Gary et al. (1983) have pointed out, the effects of cattle on water quality are difficult to assess because sporadic defections may go undetected by low-frequency and low-intensity water sampling. Our fecal coliform results from Paddy Creek show that (Table 4).

CANADIAN DRINKING WATER STANDARDS

One of the reasons for monitoring water quality is to ensure that the water is safe for human consumption. The maximum values obtained throughout the entire sampling period for each of the sampling sites are compared with the Canadian Drinking Water Standards in Table 5. For the most part, water quality values were within standards. The exception is hardness, where concentrations above the standard were recorded at all sites. There were also recorded deviations from the standards for turbidity and coliforms but as discussed above these are natural fluctuations not related to use of the area by livestock.

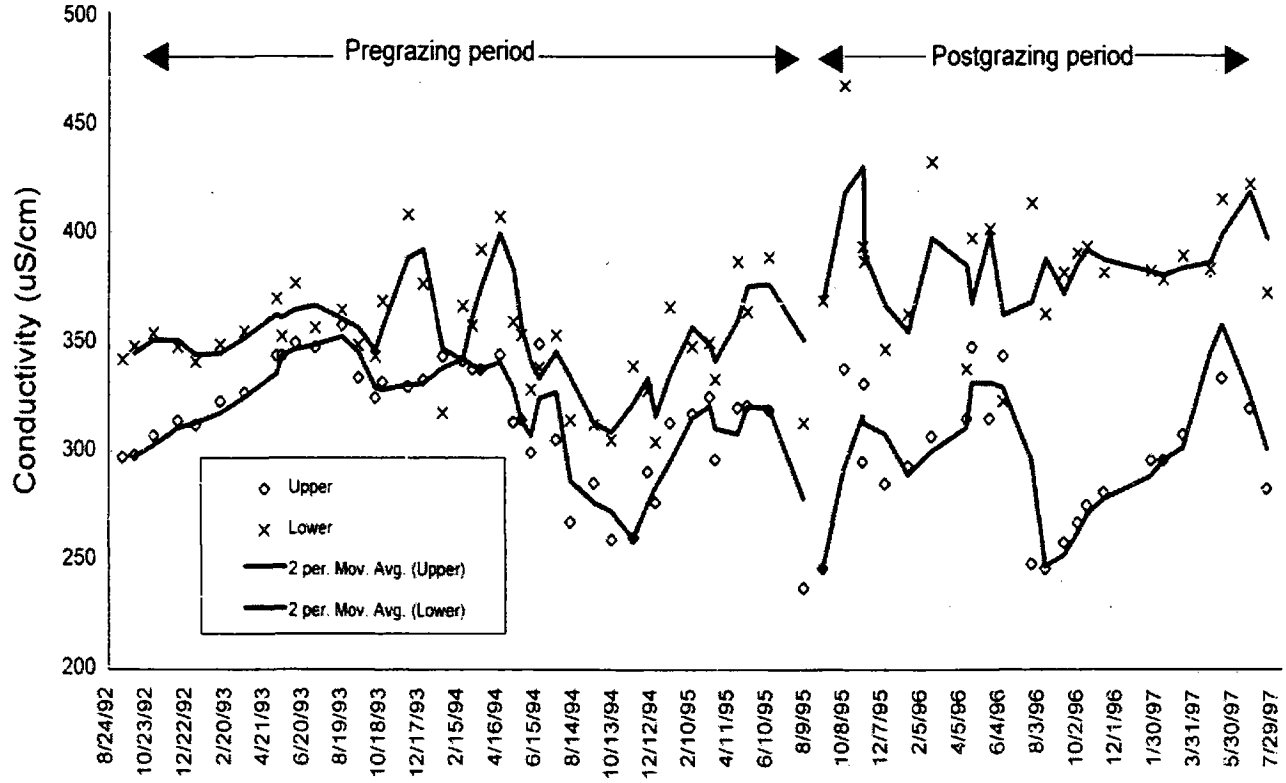

Figure 6. Time series plot for conductivity values in Paddy Creek during the sampling period.

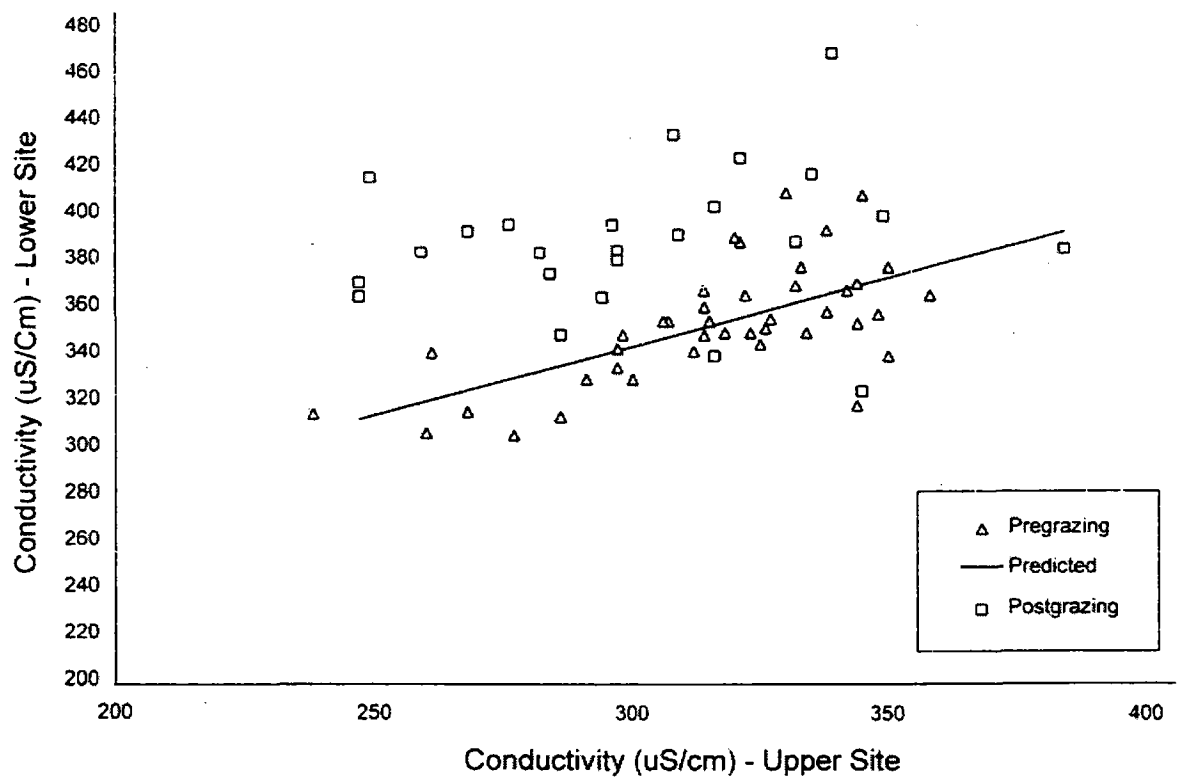

Figure 7. Prediction plot for conductivity values based on pregrazing relationship between upper and lower sites in Paddy Creek.

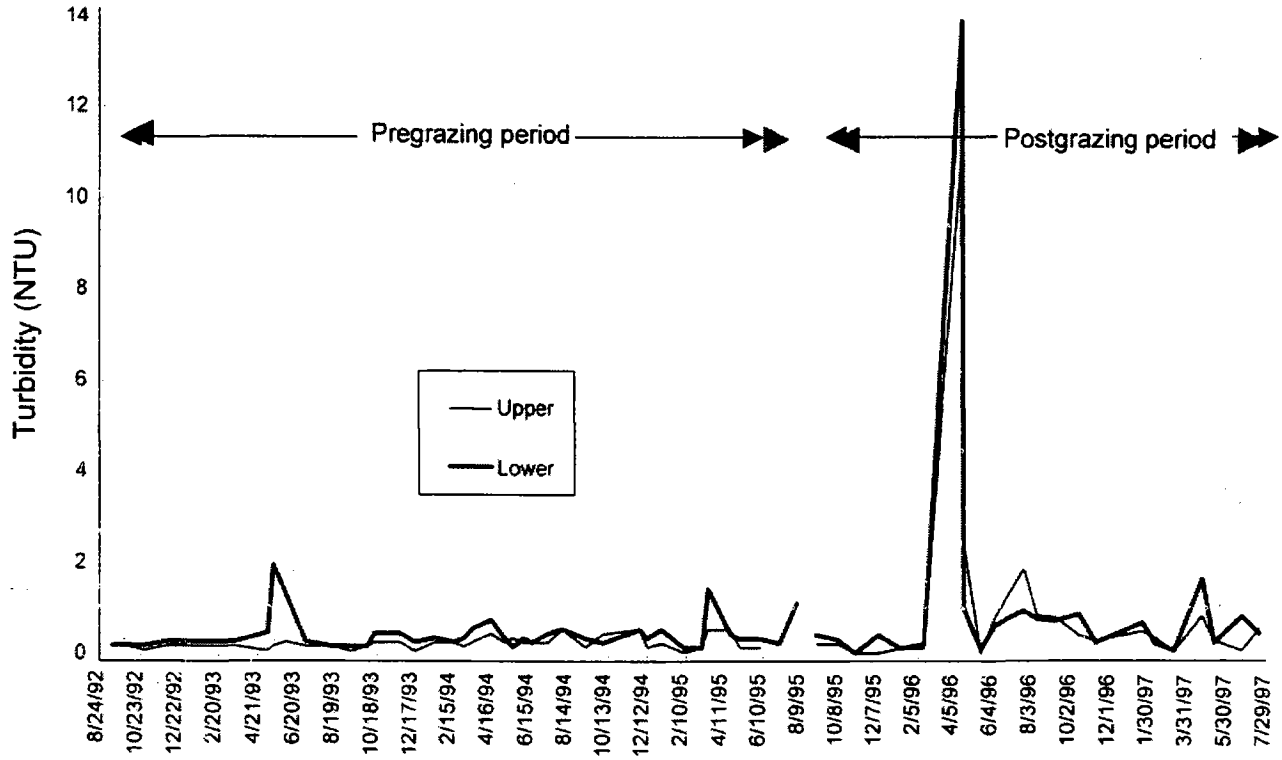

Figure 8. Time series for turbidity values in Paddy Creek during the sampling period.

Table 4. Comparison of fecal coliform measured on Paddy Creek.

	Pregrazing		Postgrazing	
	Upper	Lower	Upper	Lower
Maximum	1000	460	10	50
Sample size	66	46	68	45
Non-detectable	58	38	48	35

Table 5. Comparison of maximum measured concentrations in relation to acceptable and objective levels established for water used for domestic consumption.

Water Quality Parameter[1]	Monteagle	Paddy	Hogranch	Beards	Drinking Water Standards[2]	
					MAC[3]	AO[4]
Nitrogen: Ammonia	0.026*	0.61*	0.015	0.011*	0.5[c]	0.01[c]
Nitrogen: Organic	0.39	0.46*	0.24	0.45*		
Nitrogen: Nitrate plus Nitrite	0.15*	0.20*	0.20	0.45*	10[a]	0.001[b]
Nitrogen: Total	0.45	0.48*	0.38	0.9*		
Phosphorus: Dissolved	0.010	0.034	0.010	0.010		
Phosphorus: Total	0.04	0.151	0.168	0.361	0.2[c]	
Hardness	263	285	302	225	200[a]	80-100[a]
Calcium	61.1	70.6	71.5	50.7	200[c]	75[c]
Magnesium	27.0	26.3	30.1	25.2	150[c]	50[c]
Specific Conductance	452	469	363	411		
Turbidity	2.6	14	75	90	1	5
Coliform: Fecal			1000*		0[b]	
Coliform: Total			2420		10[b]	

[1] all values in mg/L except specific conductance (uS/cm), turbidity (NTU) and coliforms (CFU/0.1L).
[2] standards are employed from the various sources as follows:
[a] Federal-Provincial Subcommittee on Drinking Water (1989).
[b] B.C. Ministry of Health (1982).
[c] McNeely et al. (1979).
[3] maximum acceptable concentration. These are established fo substances known or suspected to cause adverse effects on health.
[4] aesthetic objectives. These apply to substances or characteristics of drinking water which can affect its acceptance by consumers or interfere with practices for supplying good water.
* maximum value recorded at the upper site.

MANAGEMENT IMPLICATIONS

The water sampling program was instrumental in assisting resource managers in evaluating the potential impacts of livestock use on the community pasture. Presenting the data annually at CRMP meetings diffused an extremely volatile situation to the point that hardly anyone attends the meetings anymore. To date, there has been no clear impact on water quality from livestock, nor has there been a sustained impact to water quality from the development of the pastures when compared to Canadian Drinking Water Standards. The monitoring also pointed out that water from undisturbed watersheds as measured at our upper site can cause concern among health officials. Monitoring water quality provided a means for water users to evaluate their water with respect to resource use.

As with other studies, the effects of livestock grazing depends upon management and climatic factors. The effects are not well understood. It is important to set up the monitoring to exclude influences external to the pastures. By sampling directly below the pasture we were able to exclude influence from activities further down-stream, which included a hydro powerline, road network, and private property. Sampling at water intakes is the practice in B.C. for ascertaining the quality of water for domestic purposes, but does not provide an accurate picture of specific land use impacts.

Although there are excellent studies elsewhere on livestock-water interactions, we found that water quality sampling provided the data and support needed to deal with the problems at the local level. The study also provided a reference point for us to deal with other water user groups demanding water quality monitoring.

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LIVESTOCK GRAZING EFFECTS ON PHOSPHORUS CYCLING IN WATERSHEDS

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ABSTRACT

Elevated phosphorus (P) loading of wetlands, streams, lakes, and reservoirs can occur from nonpoint sources such as grazing of uplands, wet meadows, and palustrine wetlands. Erosion caused by livestock grazing or any activity will increase the total P load in streams; however, herbivores can also harvest P from forage and export a significant amount of P from the watershed. Some land managers fail to recognize that the P taken up by plants will continue to cycle through soil and water. Dissolved P or P attached to soil particles suspended in water are the primary vectors of P movement in a watershed. Herbivores add another vector with more opportunities to export P from the watershed. Using best management practices such as rotational grazing, buffer strips next to wetlands, and proper irrigation management should reduce overland flow and streambank erosion. Livestock grazing should harvest and remove a significant amount of P from the ecosystem by incorporation into bone and tissue mass of growing animals and beef export from the basin. The Phosphorus Uptake and Removal from Grazed Ecosystem (PURGE) model uses three separate methods to estimate P retention in cattle, and using limits of the input variables, predicted a range from 4 to 50 Mg P could be removed annually from 17,700 ha of pasture in the Cascade Reservoir watershed in west-central Idaho. With proper grazing management, cattle should be part of a long-term solution to P loading and improvement of water quality in Cascade Reservoir.

Key words: Phosphorus, phosphorus cycling, phosphorus export, livestock grazing effects, model, nutrient

Livestock grazing on public and private lands is increasingly scrutinized for its contribution to nutrient loading of water bodies. While improvements in grazing management usually can reduce nutrient loading, P-loading due to grazing may be overestimated and goals for reduction of nutrient loading may be unrealistic. An understanding of the magnitudes and flows of P within the soil, plant, animal, and microbial pools is essential if land managers are to limit P loading in surface water.

EUTROPHICATION AND NONPOINT SOURCES OF P

The process of water bodies becoming rich in nutrients with the result of abundant microbial growth is called eutrophication. Microbial growth in fresh water systems is often limited by available P. The eutrophication process can remove oxygen from waters, resulting in the death of desirable aquatic species.

Nonpoint sources may contribute 60% of the P load to reservoirs (Valley Soil Conservation District 1991). But often "natural" or background levels prior to grazing or disturbance by man are unknown. Phosphorus load in a stream is a function of geologic materials, soils, topography, vegetative cover, precipitation intensity, and water hydraulics. The contribution of P from natural sources can be difficult to differentiate from anthropogenic sources. Abrams and Jarrell (1995) found that high native P levels and P adsorption characteristics of soils in a tributary watershed of the Willamette River were an important nonpoint source of P. Determining background levels is difficult but critical to setting realistic goals for nutrient loading and its reduction.

NUTRIENT CYCLING

Transport of P by overland flow depends on desorption, dissolution, and extraction of P from soil, and mineralization of plant material and feces. Temperature, precipitation, anaerobic soil conditions, and evapotranspiration rates further influence the process. Plant species composition and rate of decay affect the P leached from plant material. Soil P loss is dependent on

the capacity of reactive mineral and organic matter surfaces, pH, and concentrations and interactions of other elements (Broberg and Pearson 1988).

Climate is the overriding variable in nutrient loading. Separating climatic effects from any treatment of the watershed is difficult. Thus, it may be inaccurate to infer trends of P loading without accounting for yearly variation in weather effects and stream flows.

In a system without herbivores, nutrients cycle from soil to soil water, to plants, to litter, and back to soil (Fig. 1). Erosion of soil or leaching through the groundwater transports P to streams and reservoirs. When herbivores are added to the ecosystem, P may be found in more chemical forms with varying solubility. Urine and feces return unabsorbed or unretained P to the soil surface to continue cycling. Also, soluble P from plant leachate can move in overland flow into streams and reservoirs.

RESEARCH DESIGNS

Monitoring studies may be an inappropriate basis from which to infer the effects of grazing management on P loadings. For example, the comparison of one grazed watershed with an ungrazed watershed may have confounded effects with no measure of experimental error. One confounded effect is the watershed itself may be a larger source of variation than treatment; i.e., different soils, aspects, slopes, vegetative cover, etc. In another case, the comparison of P concentration above and below grazed and nongrazed pastures may be confounded by stream and soil differences. Monitoring studies are only useful in recording what happened, not why it happened. Critical studies are needed that test hypotheses of cause and effect in addition to monitoring.

Thus, objectives of this study are to review the literature on P cycling, present the relative masses of P in ecosystem components, describe a simulation model to predict P export in bodies of grazing cattle, discuss best management practices (BMPs) to limit P loading, and propose research to solve nonpoint source P loading.

METHODS

STUDY AREA

This conceptual experiment utilized data from Valley Soil Conservation District (1991) and Division of Environmental Quality (1995) as a case study of the Cascade Watershed in west-central Idaho. The watershed is 1,580 km^2 with elevations from 1,470 to 2,740 m. The mountains surrounding Long Valley are mostly Idaho Batholith except for West Mountain, which is Columbia River Basalt. The valley was formed by a down-dropped fault block which has been filled with glacial debris and alluvial material. Soils have little development.

The average annual precipitation at the city of Cascade is 554 mm and may exceed 1,270 mm at the higher elevations. Most of the precipitation occurs as snow and reaches a maximum depth of 0.3 to 1 m on the valley floor and generally exceeds 2.4 m in the higher mountains during April. The predicted average water available for runoff is 193 mm for a 15-day period (Valley Soil Conservation District 1991). Thus surface runoff would be about 140 mm. Much of the P enters wetlands as a pulse during snow melt. The land use of interest is the 17,800 ha of pastureland, 11% of the watershed.

Eutrophication of Cascade Reservoir is attributed to excess P and other nutrients entering the shallow reservoir through tributaries and irrigation return flows (Entranco Engineers 1991). Estimated sources of P (Division of Environmental Quality 1995) are agriculture (30%), forest (22%), internal recycling (19%), the McCall sewage treatment plant (11%), urban/recreation (8%), rainfall/dryfall (7%), fish hatchery (2%), waterfowl (1%), and on-site wastewater (<1%). Watershed nonpoint sources may contribute 60% of the P load (Valley Soil Conservation District 1991).

MODEL DEVELOPMENT

The Phosphorus Uptake and Removal from Grazed Ecosystems (PURGE) simulation model was developed to estimate P uptake by grass and P retention in bodies of grazing cattle (Shewmaker 1997). Input variables include known, approximate, and assumed values based on measurements, scientific literature, and personal experience. The model does not simulate water flow, soil erosion, or nutrient movement, except by means of ruminant animals. Three methods within the model estimate P exported in cattle tissue.

Method #1 uses net P absorption by animals, daily dry matter (DM) consumption, cattle weight, P concentration in grass, stocking rate, and area grazed as the input variables. These values are multiplied as linear combinations to calculate carrying capacity, total weight gain, grass consumed, P consumed, P retained, and P removed with cattle. Values for net P adsorption are assumed based on Agricultural Research Council (1980) and Miller (1979). The P concentration in grass is assumed to be from 0.18 to 0.30 % reported by Kincaid (1993), Follett and Wilkinson (1995), and data from our lab.

Method #2 uses forage production (Valley Soil Conservation District 1991), P concentration in grass (from Method #1), and the ratio of P removed per plant uptake (Cohen 1980) as input variables. These values are multiplied in linear combinations to calculate P removed by cattle on an area basis and total P removed from the area grazed.

Method #3 was suggested by R.C. Bull, animal scientist at the University of Idaho (personal communica-

tion 1996). The P composition of bone and soft tissues in cattle is highly predictable and therefore P export is easily calculated from cattle weight gain while on the pastures. The P content of wet bone tissue is 4.5% (Church 1971), and 80% of total body P is found in the skeleton and teeth. The acreage and weight gains used are those described in Method #1. Based on these assumptions, the values are multiplied to calculate weight gain as bone, bone P, and non-bone P from animal gain. The P in bone growth and non-bone P is added to calculate total P from animal mass gain.

RESULTS

THE SOIL POOL

Soil P is the largest pool by far; however, much of this P is not immediately available. Soils in the Pacific Northwest plus most of Nevada, Utah, and Wyoming generally contain from 0.2 to 0.3 % total phosphate (P_2O_5) in the surface foot of soil (Tisdale et al. 1993). Organic forms of P usually decrease with depth, vary from 15 to 80%, and average 50% of total soil P. If a soil contains 4% organic matter in the surface 15 cm, the organic P content (assuming P is 1% of the organic matter) is (Tisdale et al. 1993):

2.24×10^6 kg soil/ha—15 cm x 0.01 x 0.04 = 896 kg organic P/ha to 15 cm

Soil P may be immobilized to organic forms or chemically fixed inorganic P. Organic P must be mineralized to the inorganic form to be taken up by plants. Inorganic P in solution which is not absorbed by plants or immobilized by microorganisms can be adsorbed to mineral surfaces (labile P) or precipitated as secondary P compounds. Soil pH has a large effect on P fixation or retention. In acid soils, P precipitates as Fe/Al secondary minerals or is strongly sorbed to clay and metal oxide surfaces. In calcareous soils (pH 8), P precipitates as Ca-P secondary minerals or is adsorbed to $CaCO_3$ (Tisdale et al. 1993). Precipitation reactions will occur when the concentration of P and associated cations in the soil solution exceeds the solubility product of the mineral.

Flooding generally increases available P due to conversion of Fe^{3+} phosphates to more soluble Fe^{2+} phosphates and hydrolysis of Al phosphate (Tisdale et al. 1993). Flooding or saturated soil moisture provide anaerobic conditions needed for the microbial population to reduce the Fe^{3+}. This process also generally occurs at pH near neutral.

THE PLANT POOL

The plant pool contains the next largest P source. Phosphorus concentrations in forages may range from 0.14% to over 0.30% P (Follett and Wilkinson 1995). Inorganic P ($H_2PO_4^-$ or HPO_4^{-2}) is taken up by plant roots and most is converted to organic forms upon entry into the root or after it has been transported through the xylem.

What happens to P in plants as plants die or become senescent? Leaves, stems, and roots decompose by weathering and microbial assimilation of nutrients. Nutrients are recycled to the soil by mineralization, where they remain until absorbed by plants or leached from the soil into water bodies. While P losses from live plants are small, 69-80% of total P may be leached from plant residue (Harley et al. 1951; Timmons et al. 1970: c.f. Mays et al. 1980). Much water-soluble P is assimilated by microbial activity and converted back into organic forms. Precipitation intensity and duration, the time between plant dormancy or senescence and the first precipitation, affect the P returned to the soil or lost in runoff (Mays et al. 1980).

THE WATER POOL

Elevated phosphorus (P) loading of wetlands, streams, lakes, and reservoirs can occur from nonpoint sources such as grazed uplands, wet meadows, seasonally flooded, and saturated wetlands. Erosion caused by livestock grazing or any activity will increase total P load in streams.

The Environmental Protection Agency (1989) recommends total P not exceed 0.05 mg/L for a stream at the point where it enters a lake or reservoir, 0.025 mg/L for reservoirs, and 0.10 mg/L for free-flowing rivers. The total P in 1-m depth of reservoir or lake surface water would contain 0.25 kg total P/ha if the concentration was at the Environmental Protection Agency recommended limit. The average total P concentration in Cascade Reservoir ranged from 0.019 to 0.031 mg/L in 1974 (Division of Environmental Quality 1995). Reservoir concentrations ranged from 0.018 to 0.102 mg/L during the period 1978 through 1982 (Zimmer 1983).

Direct rainfall contributed an estimated 0.175 kg P/ha lake surface for water years 1975 and 1981 (Environmental Protection Agency 1977). An assumed value of 0.05 mg P/L multiplied by rainfall volume was used by Division of Environmental Quality (1995) to estimate P content of rainfall when actual measurements are not available. Internal recycling may contribute 19% of the P load in the reservoir (Division of Environmental Quality 1995).

THE ANIMAL POOL

Phosphorus mass in the animal pool will be less than the plant pool (Table 1) if P is not imported as feed supplement. Grazing livestock utilize the forage plant material and recycle most nutrients back into the system. Herbivores add another vector with more opportunities to export P from the watershed (Fig. 1). The net P absorption by cattle is about 90% efficient in young calves and 55% efficient in cows. Bone tissue contains 4 to 4.5% P

Table 1. Hypothetical effects of forage utilization by cattle on recycling of P from plant residue or animal excreta.

Forage Utilization	Soil	Surface Water to 1 m	Plant uptake	Litter return	Animal product	Feces return	Stocking density
%			kg P/ha				head/ha
0	1875	0.25	15	15.0	0.0	0.0	0.00
25	1875	0.25	15	11.3	0.4	3.4	0.17
50	1875	0.25	15	7.5	1.5	6.0	0.33
75	1875	0.25	15	3.8	3.4	7.9	0.50
100	1875	0.25	15	0.0	6.0	9.0	0.67

Assumptions: The P concentration in the surface 15 cm of soil averages 0.1% P. The bulk density is 1.25 Mg/m3. The surface water to a 1 m depth averages 25 ug/L. Net primary production is 6,000 kg of dry herbage/ha containing 0.25% P. The retention of P in the cattle is 60%. It requires 9,000 kg/ha to be consumed to produce a 400-kg calf containing 2.66 kg of P. Therefore, at a herbage utilization efficiency of 25%, 6 ha will be required; at a utilization efficiency of 75% only 2 ha is required. (After Mays et al. 1980) Fresh bone contains 4.5% P, bone P accounts for 80% of total body P, and bone growth is about 20% of the animal growth (Church 1971).

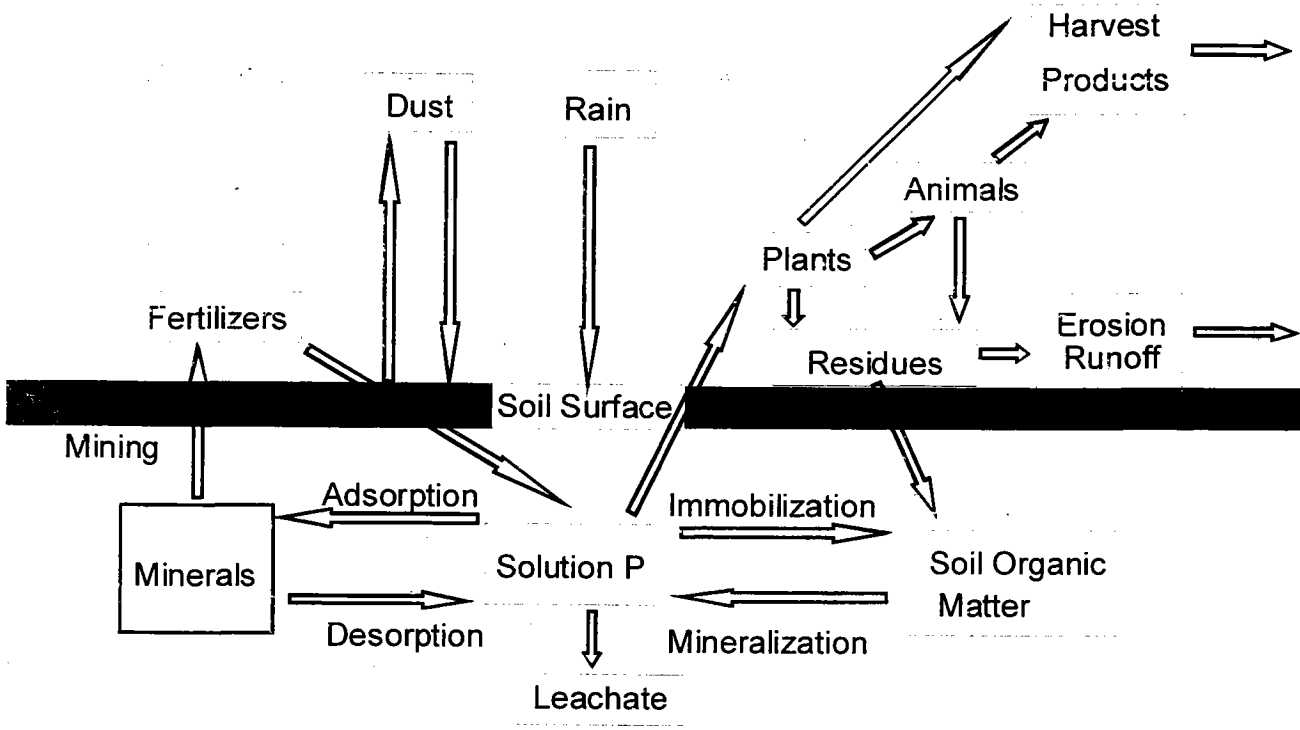

Figure 1. The P cycle on a grazed pasture.

(Church 1971), and from 75 to 80% of total body P is found in the skeleton and teeth. Phosphorus uptake in cattle with daily gains of 0.5, 0.75, and 1 kg/head would be 0.2, 0.88, and 2.16 kg/ha, respectively, during the grazing season (see Method #2, Table 2).

Phosphorus in the diet of grazing animals which is not retained is excreted primarily in the feces. About 0.06 g of organic P is excreted per 100 g of feed eaten (Barrow 1975). Sheep feces retained 40% of the initial total P after 2 years of exposure to weathering and 100 cm of rain (Bromfield & Jones 1970), and 90% of the residual P was in the organic form. Floate (1970a,b,c,d) concluded that organic P in both plant and animal residues appeared to be more of a sink than a source of P cycling.

LIVESTOCK GRAZING EFFECTS ON P CYCLING

A simplistic P budget on grazing land is represented in Table 1. The magnitude of P in plant litter decreases linearly as herbage utilization increases, and the magnitude of P in animal product and dung increases linearly. All of the plant P is recycled unless removed by harvesting

Table 2. Simulations of P export produced by the PURGE model.

	A	B	C	D	E
1	PURGE4.WB2 Sheet D:	**P Uptake and Removal from Grazed Ecosystems**			
2					
3	**Plant Material on dry matter basis**		**Scenarios**		
4	**Method #1**	**Formula**	**1**	**2**	**3**
5	***Assumptions:***				
6	Net P absorption (%)		80%	70%	60%
7	yearling wt (kg)		250	300	350
8	daily DM consumption (%)		2.50%	2.75%	3.00%
9	P conc. in grass (%)		0.25%	0.28%	0.30%
10	stocking rate (hd-mon/ha)		3	4	5
11	area grazed (ha)		17,668	17,668	17,668
12	rate of gain (kg/hd-day)		0.5	0.75	1
13	***Calculations:***				
14	carrying capacity (hd-mon)	+B10*B11	53,004	70,672	88,340
15	total weight gain (Mg)	+B14*B12*30/1000	795	1,590	2,650
16	grass consumed/hd-day (kg)	+B7*B8	6.25	8.25	10.5
17	P consumed/hd-day (kg)	+B16*B9	0.02	0.023	0.032
18	P retained/hd-day (kg)	+B17*B6	0.01	0.016	0.019
19	**P removed with cattle (Mg)**	+B18*B14*30/1000	19.88	34	50
20					
21	**Method #2**				
22	***Assumptions:***				
23	forage production (kg/ha)		2,000	4,000	6,000
24	P conc. in grass (%)		0.25%	0.28%	0.30%
25	ratio of P removed/plant uptake		0.04	0.08	0.12
26	***Calculations:***				
27	P removed with cattle (kg/ha)	+B23*B24*B25	0.2	0.88	2.16
28	**P removed from watershed (Mg)**	+B11*B27/1000	3.53	16	38
29					
30	**Method #3 (Bull 1995)**				
31	***Assumptions:***				
32	same total weight gain as above		fresh bone = 4.5% P		
33	bone growth is about 20% of the animal growth		bone P = 80% of total body P		
34	***Calculations:***				
35	weight gain as bone (Mg)	+B15*0.2	159	318	530
36	P in bone growth (Mg)	+B35*0.045	7	14	24
37	non-bone P from gain (Mg)	+B36/4	2	4	6
38	**Total P from gain (Mg)**	+B36+B37	9	18	30

hay or by grazing. If P is not supplemented, and grazing animals gain weight and are removed from the watershed, then P is exported in the animal tissue.

The amount of P exported with grazing cattle estimated by the PURGE model is shown in Table 2. Depending on the scenario and method used within the model, the amount of P exported varied from 4 to 50 Mg per 17,700 ha. An average of the moderate values (scenario 2) across the three methods results in 23 Mg P removed from 17,700 ha of pasture lands in the Cascade Watershed annually.

DISCUSSION

THE P CYCLE ON A GRAZED OR HAYED PASTURE

Effects of livestock grazing on nutrient loading are reported with mixed conclusions. Some report that grazing has no measurable impact on N and P pools in soils of infrequently flooded, upland grasslands. Other and sometimes nonscientific papers report that grazing increases P in streams, but these monitoring studies often have inappropriate designs for determining cause and effect. It is clear that any activity accelerating erosion will increase total P load. It isn't clear what effects grazing has on soluble P loading to streams and reservoirs.

Proper grazing management is essential to reducing nutrient loadings to streams. In Oklahoma, Olness et al. (1980) reported that total P concentrations in surface runoff from continuously grazed watersheds ranged from 1 to 1.8 ppm, and were about three times higher than those from rotation-grazed watersheds because of greater soil loss. Average annual losses in runoff from the same rotationally grazed and continuously grazed watersheds were 0.56 and 1.9 kg total P/ha, respectively (Menzel et al. 1978), over a 4-year period. In contrast, Tiedemann et al. (1989) found that differences among grazing strategies for P concentration in streamwater were not significant after the average daily streamflow was used as a covariate in a 5-year study on 13 wildland watersheds in eastern Oregon. In northern Idaho, Jawson et al. (1982) reported annual total P losses in runoff from a grazed watershed over 3 years ranged from 0.1 to 1.3 kg/ha and from 0.1 to 0.17 kg/ha for the ungrazed watershed. However, the watershed effect may be confounded in the study and comparisons are difficult because of differences in topography, vegetative cover, and intensity of precipitation.

There may be a potential for livestock grazing to increase P loading in overland flow situations because the eating and digestion of plant material reduces the particle size in the fecal material containing the undigested P. However, much of the P in the undigested plant material may be in insoluble forms.

Much of the P cycled through animals returns to the surface as dung pats but patterns of dung and urine deposition are not uniform. Such patterns may be more distinct with sheep where from 1 to 2 kg P/ha annually may be transported to ridges where sheep camp at night (Haynes & Williams 1993). Theoretically a BMP of high-intensity and short-duration grazing should provide more uniform dung distribution. However, in a Florida study, soil P redistribution was not different among short-duration, long-duration, and continuous grazing systems on Bermuda grass, but accumulated in the third of the pastures closest to shade and water, probably a result of urine and feces deposition by cattle (Mathews et al. 1993).

Livestock grazing, assuming it is performed with best management practices, in fact removes P from the ecosystem, thereby reducing the extractable soil P. This should produce a greater P sink capacity in the soil because the Fe and Al oxides would still be available to adsorb P from leached plant residue, feces, and urine or from infiltration of water into the soil.

EXPORT OF P

Using moderate values in the PURGE simulation, the model produced an estimate of 23 Mg P removed from the basin, or 1.3 kg P/ha removed. Linqian and Tingcheng (1993) reported that native range in northeastern China dominated by *Leymunes chinenses* could have 1.5 kg P/ha exported annually as hay, which was 21% of the P balance. Wilkinson (1973) calculated that a grazing 500 kg bovine removed 3.3 kg P from the soil into the animal body, while removing 11 Mg of tall fescue hay exported 38 kg P/ha.

Lavado et al. (1996) reported lower soil extractable P in grazed pastures than in pastures excluded from grazing for 13 years on the Pampas in Argentina. Similarly, total P was 4 kg/ha larger in relict than grasslands grazed for 75 years on the Great Plains (Bauer et al. 1987). Diarra et al. (1995) reported 0.15 kg P/ha exported as animal product from the arid Sahel.

Martin and Molloy (1971) estimated the amount of organic P annually contained on a grazed pasture was 269, 6.2, 9, and 3 kg P/ha for a 7.6-cm soil depth, feces, residual herbage, and roots, respectively. They estimated inorganic P annually contained on a grazed pasture was 470, 35, 13, and 4 kg P/ha for a 7.6-cm soil depth, feces, residual herbage, and roots, respectively. The inorganic P in feces seems high in this data and could result from some soil contamination.

RESEARCH AND MANAGEMENT IMPLICATIONS

RECOMMENDATIONS OF BEST MANAGEMENT PRACTICES

Grass buffer strips can be effective in reducing P transport from pastures by increasing infiltration, sedimentation, and decreasing overland flow. Off-stream water development and fencing of riparian areas should reduce (1) streambank degradation, and (2) direct deposit of feces and urine in streams. Rotational grazing systems should provide for a healthier pasture.

Degraded water quality is not beneficial to recreationists, wildlife, homeowners, or agricultural producers. Everyone benefits from using BMPs and other tools—based on science rather than perceptions—to reduce P loading. Recreational and grazing activities that accelerate erosion will increase total P loadings because of P association with soil particles. We should also recognize that properly managed livestock grazing operations will export P from the basin.

RESEARCH NEEDS

The effects of grazing need to be determined by using a design of randomized and replicated treatment areas within the same watershed, and multiple years and watersheds. Volume and nutrient concentration of overland flow and leachate should be measured on these plots as often as every other day during peak snow melt conditions, and as often as twice per week during the grazing season. Overland flow and leachate should be monitored during high, medium, and low runoff years, and total and soluble P concentration should be measured in the soil, forage, and feces in temporal and spatial scales. Cattle gains should be recorded to verify the input variables used in this model. By using a mass balance approach, accounting for most of the P cycling in the ecosystem should be possible. Radioactive isotopes also could be used to trace P cycling in extracted soil cores. Knowing the cycling times and forms should provide insight into adjusting BMPs.

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CONCEPTUAL CRITERIA FOR GUIDING WATERSHED PLANNING, ACTIVITIES, AND MANAGEMENT

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ABSTRACT

Watershed planning is typically initiated (or cyclically reinitiated) by one or two overriding resource issues that act as rally points to stimulate planning and management activities by stakeholders. A comprehensive assessment of watershed resource conditions and related ecosystem functions may be overlooked when just a few issues preoccupy the thoughts and actions of stakeholders and technical support specialists. To avoid this phenomenon, a set of ecosystem-based "framing" questions can serve as diagnostic criteria for revealing watershed condition ailments associated with human management. These criteria can link to indicators of ecological, economic, and social conditions which will likely include but go beyond the initial rally issues.

Key words: Criteria, framing questions, indicators, watershed planning, watershed management, ecosystem-based assistance

Watershed planning and subsequent management are commonly initiated by one or two overriding resource issues that act as rally points to stimulate stakeholder interest and involvement. A comprehensive assessment of watershed resource conditions and related ecosystem functions may be overlooked when just a few issues preoccupy the thoughts and actions of stakeholders and supporting technical specialists. To avoid this phenomenon, a set of ecosystem-based "framing" questions were developed to serve as the conceptual foundation or criteria for revealing watershed condition ailments associated with human management.

INTRODUCTION TO FRAMING QUESTIONS

The Natural Resources Conservation Service (NRCS) has provided watershed planning and management assistance to food and fiber producers and natural resource managers and stakeholders since shortly after the agency was formed in 1935. The context for this assistance has been watersheds that were controlled and operated predominantly by private owners. Currently, most administrative offices of the NRCS at the state and regional level employ technical staffs specifically devoted to watershed planning and management. These staffs typically deal with one or two dominant watershed issues that have been previously identified by stakeholders or, in more recent times, inspired by land management regulators.

To better serve clientele, the NRCS in the 1990s embarked on expanding and refining the context for giving assistance by looking into such concepts as:

* Conservation tillage systems

* Quality criteria attainment for Soil, Water, Air, Plants, Animals and Human conditions (referred to as "SWAPAH") at the farm level

* Low-input, sustainable agriculture

* Agroforestry and conservation buffer systems

* Areawide conservation planning and assistance

* Ecosystem-based assistance

The development team for the concept (and goal) of "ecosystem-based assistance" was formed to address a more holistic approach to areawide or watershed-level management assistance by NRCS and partner organizations (NRCS 1996). Three outcomes from this effort were: 1) acknowledgment that quality criteria for SWAPAH used within NRCS at the farm level adequately supports assistance given to clients for the management of ecological, economic, and social conditions and resources, 2) recognition that a comparable set of criteria at the watershed level was not available, and 3) formulation of ecosystem-based and watershed-level criteria in the form

of "framing" questions. (Note: A questions-type format was used to accommodate a more decisive "yes-no" logic in pondering criteria.)

The last product, framing questions, represents a related and comprehensive set of broad, diagnostic questions for identifying or "scoping" the ecological, economic, and social conditions and issues within any large area, e.g., watershed. The questions, listed below, cover 10 facets of an area's ecosystem and include humans as an integral component.

1. Are precipitation and groundwater resources captured, stored, used, and released in a safe and stable manner?

2. Are kinds and flows of chemicals (minerals, nutrients, other) and energy in balance and optimized for plant and animal communities and biomass production requirements?

3. Are annual cash flows, technical assistance, and conservation incentives timely and adequate for desired community and land user incomes?

4. Are soil, water, air, plant, and animal resources and biophysical processes in place and in a condition to allow timely and full recovery from stresses and disturbances and to meet management objectives?

5. Are social and economic systems available to allow land users and communities and the resources they manage to recover from environmental and socioeconomic stresses?

6. Are there human and animal resource health concerns associated with the management of present or planned enterprises?

7. Do landscape features and patterns facilitate use, protection, and optimization of ecosystem processes?

8. Do commodity markets, investment capital, and public programs encourage land uses, enterprises, and resource management that are compatible with ecosystem processes?

9. Are decision-making processes available to communities and individuals to resolve conflicts regarding current and desired uses, management, and protection of natural resources?

10. Does the social infrastructure (health care, education, multi-culture recognition, etc.) support and promote the desired quality of life for the communities and individuals?

These questions are not easily answered but can quickly generate discussion among stakeholders and technical specialists familiar with a particular watershed. The questions provide a conceptual foundation for a consistent, permanent set of queries about any area (or watershed) which allow the construction of pertinent and tailored assessments of resource conditions, perceived issues, and current and planned management activities.

LINKAGE TO RESOURCE CONDITIONS, INDICATORS, AND THRESHOLD VALUES

Associated with each framing question are key resource conditions, ecosystem processes, and functions. For a simplified example, answering question 1 with a "yes" indicates that precipitation and groundwater resources are captured, stored, used, and released in a safe and stable manner. This means that there is little or no accelerated surface soil erosion (i.e., erosion from human activities which exceeds natural, geologic erosion), runoff flows are similar to expected and natural hydrographs, and aquifer levels may fluctuate but are relatively consistent and follow the perturbations of climate cycles. Some key assumptions in this simplified conceptual example include that the natural circumstances for the hydrologic cycle are known or can be inferred, that natural disturbances (e.g., wildfire, drought, floods) are taken into account and not mistaken for human-caused disturbances, and that the watershed has a uniform condition in terms of water resources.

Within each of these resource conditions or processes, certain indicators can be chosen to act as yardsticks to measure performance status ... and ultimately, if threshold values for indicators are established, as technical or decision standards leading to more detailed investigations and remedial management actions. Using the illustration of accelerated surface soil erosion, consider the scheme of threshold values and interpreted condition classes displayed in Table 1 associated with the indicator, sheet/rill erosion.

Table 1 illustrates a simple case of a single framing question and some associated resource conditions indicators and threshold values. It is envisioned that for a target watershed a team of stakeholders and technical support specialists would establish an investigation list of applicable condition indicators and threshold values for all framing questions based on expert knowledge and discussion. Further, there is a strong expectation that a different list of indicators and values would (must!) be developed for each of the various partitions and subpartitions of a watershed, e.g., ecoregion-habitat, land use-class, or other attribute complex used to address framing questions.

The use of framing questions will help: 1) ensure that one or two heated issues will not overshadow the deliberate and comprehensive assessment of watershed resource conditions, 2) establish an ecosystem-based, conceptual foundation (humans as an integral part) as a starting point, and 3) provide a consistent approach to assessment and management of adjacent (or distant) watersheds.

Table 1. A simple case showing indicators, threshold values and interpretations associated with a *framing question* for a uniform-condition watershed.
(For illustration only.)

Framing Question: Are precipitation and ground water resources captured, stored, used and released in a safe and stable manner?	
Indicator[1] -- Threshold Values: Accelerated surface erosion -- sheet/rill erosion (weight/unit area/year) and gullies (observed frequency).	*Interpreted Condition Class: ("Health" Tendency)*
Erosion rates on any land uses above "4T[2]"; active gullies frequently observed.	Degraded, recovery doubtful
Erosion rates on any land uses "3-4T"; active gullies common.	Degraded, recovery difficult
Erosion rates on any land uses "2-3T"; active gullies limited but common in some local areas.	Degraded, readily recoverable
Erosion at "1-2T"; active gullies forming in some areas.	Sustainability at risk
Erosion below "T"; no active gullies.	Presumably sustainable

[1]Based on preponderance of observations of key land uses throughout study area; critical or problem conditions on small, limited-extent land uses or point-source areas may alter an interpretation 1 or 2 classes upward.
[2]T refers to tolerable soil loss as determined by NRCS for representative soils of the study watershed.

A WATERSHED MANAGEMENT SCORECARD USING CONDITION INDICATORS—A CONCEPTUAL SCHEME

The cumulative measurement and interpretation of resource condition indicators used to answer the 10 framing questions can show the status of resources within a watershed. Table 2 gives a simplified example of how framing questions, indicators, and threshold values can interrelate and be used for scoring or ranking the "health" of an area or watershed. (For ease of illustration, the scorecard is based on a uniform-condition watershed with just a single set of indicators.)

Even though indicators can be sampled intensively, the accuracy of any "health" rating is qualitative because of the interpretive nature of condition classes. However, as watershed assessment progresses from expert opinions to rapid analysis techniques to aggregation of detailed inventories, the scoring ("answers" to framing questions) can assume an accuracy meaningful and usable to stakeholders for management purposes.

LITERATURE CITED

Natural Resources Conservation Service (NRCS), USDA. 1996. Final Report of the Ecosystem-Based Assistance (EBA) Indicators Action Team. Washington, D.C.

Table 2. Simplified scheme relating *framing questions*, indicators and threshold values to determine watershed "health." (For illustration only.)

Score Card -- Areawide Qualitative Assessment

Ecological Framing Questions	Sample Indicators	Functional Condition Classes TENDENCY SCORE (based on preponderance[1] of observations of key land uses throughout study area) 0	2	4	6	8 10
		Degraded, recovery doubtful	Degraded, recovery difficult	Degraded, readily recoverable	Sustainability at risk	Presumably sustainable
			Sample	*Threshold Values*	*and Descriptions*	
1. Are precipitation and ground water resources captured, stored, used and released in a safe and stable manner? *(Score: _____)*	• Accelerated surface erosion • Behavior and storage of runoff (land cover) • Aquifer status	Surface erosion rates on any land uses above "4T"; active gullies frequently observed; streams deeply entrenched and/or bank erosion frequent; impervious areas >50%[2]; historical aquifer levels depleted for both domestic and agricultural use.	Surface erosion rates on any land uses "3-4T"; active gullies common; streams moderately entrenched and/or bank erosion common; impervious areas 35-50%[2]; historical aquifer levels depleted for agricultural use.	Surface erosion rates on any land uses "2-3T"; active gullies limited but common in some local areas; streams moderately entrenched and/or limited bank erosion; impervious areas 25-35%[2]; historical aquifer levels depleted but still used for domestic and agricultural use.	Surface erosion at "1-2T"; active gullies forming in some areas; streams slightly entrenced and banks stable (for stream type); impervious areas 15-25%[2]; historical aquifer levels beginning to lower due to domestic or agricultural use.	Surface erosion below "T"; no active gullies; streams not entrenched and banks stable (for stream type); impervious areas <15%[2]; historical aquifer levels maintained.
2. Are kinds and flows of chemicals (minerals, nutrients, other) and energy in balance and optimized for plant and animal communities and biomass production requirements? *(Score: _____)*	• Nutrient cycle/budget • Salt accumulations • Organic matter (OM) status and trend	Determined by stakeholders and technical support specialists.				

Table 2. (Continued)

Score Card -- Areawide Qualitative Assessment

Ecological Framing Questions	Sample Indicators	Functional Condition Classes TENDENCY SCORE (based on preponderance[1] of observations of key land uses throughout study area) 0 / 2 / 4 / 6 / 8 / 10				
		Degraded, recovery doubtful	Degraded, recovery difficult	Degraded, readily recoverable	Sustainability at risk	Presumably sustainable
			Sample	*Threshold Values*	*and Descriptions*	
3. Are annual cash flows, technical assistance & conservation incentives timely & adequate for desired community and landuser incomes? *(Score: _____)*	• Profits • Technology adoption					
4. Are soil, water, air, plant and animal resources and biophysical processes in place and in a condition to allow timely and full recovery from stresses and disturbances and to meet management objectives? *(Score: _____)*	• Observations of tolerance to drought, flooding, fire and pest infestations	Determined by stakeholders and technical support specialists.				
5. Are social and economic systems available to allow landusers and communities and the resources they manage to recover from environmental and socioeconomic stresses? *(Score: _____)*	• Availability of emergency funds • Loan and grant availability					

Table 2. (Continued)

Score Card -- Areawide Qualitative Assessment

Ecological Framing Questions	Sample Indicators	Functional Condition Classes TENDENCY SCORE (based on preponderance[1] of observations of key land uses throughout study area) 0 / 2 / 4 / 6 / 8 / 10				
		Degraded, recovery doubtful	Degraded, recovery difficult	Degraded, readily recoverable	Sustainability at risk	Presumably sustainable
			Sample	*Threshold Values*	*and Descriptions*	
6. Are there human and animal resource health concerns associated with the management of present or planned enterprises? *(Score: _____)*	• Health and accident statistics					
7. Do landscape features and patterns facilitate use, protection and optimization of ecosystem processes? *(Score: _____)*	• Flooding damage locations and statistics • Indigenous wildlife movement (seasonal, year-long)	Determined by stakeholders and technical support specialists.				
8. Do commodity markets, investment capital and public programs encourage land-uses, enterprises and resource management that are compatible with ecosystem processes? *(Score: _____)*	• Profitability • Compliance of land managers and developers with environ-mental protec-tion rules and regulations					

Table 2. (Continued)

Score Card -- Areawide Qualitative Assessment

Ecological Framing Questions	Sample Indicators	Functional Condition Classes TENDENCY SCORE (based on preponderance[1] of observations of key land uses throughout study area) 0 / 2 / 4 / 6 / 8 / 10				
		Degraded, recovery doubtful	Degraded, recovery difficult	Degraded, readily recoverable	Sustainability at risk	Presumably sustainable
			Sample	*Threshold Values*	*and Descriptions*	
9. Are decision-making processes available to communities and individuals to resolve conflicts regarding current and desired uses, management and protection of natural resources? *(Score: _____)*	• Coordinated resource management planning activity by key stakeholders • Presence of government-sponsored panels, forums, councils	Determined by stakeholders and technical support specialists.				
10. Does the social infrastructure (health care, education, multi-culture recognition, etc.) support and promote the desired quality of life for the communities and individuals? *(Score: _____)*	• Human health care and education statistics • Surveys of satisfaction with resources and habitat					
Total Score:		(100 pts. possible)				

[1]Critical or problem conditions on small, limited-extent land uses or point-source areas may alter a rating 1 or 2 classes to the left.
[2]Sufficient wetlands and buffers have capacity to store runoff on altered watersheds to alter a rating 1 class to the right

An Ecosystem Diversity Matrix for Riparian and Wetland Systems

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ABSTRACT

One of the primary barriers to effective implementation of ecosystem management across broad landscapes is the limitations inherent in existing vegetation/habitat classification systems. Of particular concern is the inability of existing classification systems to integrate ecosystem components, such as terrestrial and riparian/wetland. The development of classification systems which allow for the integration of ecosystem components is particularly important for understanding ecosystem processes, distribution of biodiversity across a landscape, as well as disturbance ecology. An Ecosystem Diversity Matrix (EDM) was developed as a landscape classification tool that incorporates an ecologically based classification system, disturbance ecology, and successional trajectories. The EDM for forested systems has been in use by Boise Cascade's Idaho Ecosystem Project for several years. The EDM is the primary tool utilized in an ecosystem management process. This paper introduces the EDM for riparian/wetland and provides a description of its usefulness in landscape assessment and biodiversity documentation. In addition, the importance of the riparian/wetland EDM as a zone of integration between upland and aquatic communities is also discussed.

Key words: ecosystem management, riparian, wetlands, ecosystem diversity matrix, ecological classification, biodiversity

One of the greatest challenges to the implementation of ecosystem management is integrating and applying the information available within the various scientific disciplines in a way that allows us to make sense of all the ecosystems present on a given landscape. This has been particularly challenging for riparian and wetland systems, as they represent the ecological interface between terrestrial and aquatic environments and consequently have been studied by a diversity of scientific disciplines, each further representing a diversity of objectives and perspectives. Not surprisingly, the end result has been a variety of classification systems, definitions, and boundary delineations depending on the scientific discipline involved. This has made it both confusing and difficult to apply existing riparian and wetland information at the landscape level. While most can agree on the value of these systems to the overall function and integrity of the terrestrial and aquatic environments, the lack of a landscape understanding of riparian and wetland systems results in considerable debate on the appropriate management and restoration objectives for these important components of the landscape.

Ecosystem management concepts emphasize the importance of understanding the past, current, and future influences on the physical and biological components of the landscape. Ecosystems are dynamic, constantly responding both physically and biologically to various types and levels of disturbance (Pickett and White 1985). The result is a potential range of conditions expressed at different temporal and spatial scales across the landscape. To identify this range of conditions and their resulting influences on biodiversity and ecosystem processes requires stratifying the landscape using an ecological classification system while also providing a mechanism for understanding historical disturbance regimes and their influence on successional trajectories. Currently, one of the primary barriers to the effective implementation of ecosystem management has been the limitations inherent in existing vegetation/habitat classification systems. These limitations are three-fold: 1) few existing classification systems adequately describe the potential range of conditions for a given landscape as influenced by historical disturbance regimes, 2) few existing classification systems adequately capture the complexity of ecological communities to quantify differences in species distributions across the landscape, and 3) few existing classification systems integrate between the terrestrial systems, riparian and wetland systems, and aquatic systems in a

manner which allows us to adequately describe and understand ecological processes and distribution of biodiversity across a landscape.

To address the limitations inherent in existing classification systems, Haufler (1994) developed a tool known as the ecosystem diversity matrix (EDM). The focus of this paper is to present an EDM for riparian and wetland systems that utilizes existing classification systems from several different scientific disciplines. The riparian/wetland EDM will be discussed in terms of its ecological framework, mechanisms to describe historical disturbance regimes and its integration with adjacent terrestrial and aquatic classification systems. In addition, we will provide a brief discussion of how the riparian/wetland EDM is being used to understand the distribution of biodiversity across the landscape. The riparian/wetland system EDM as presented in this paper applies specifically to the Idaho Southern Batholith landscape (Figure 1); however, the framework can be used to develop a riparian/wetland EDM for any ecologically defined landscape.

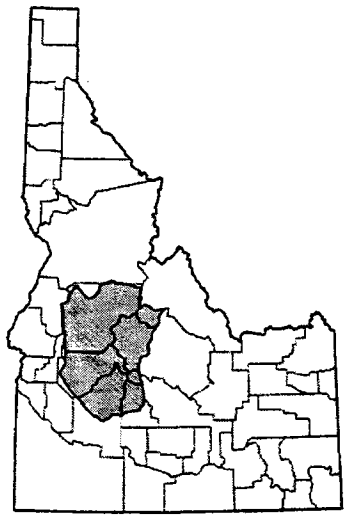

Figure 1. The Idaho Southern Batholith planning landscape (Haufler et al. 1996).

ECOSYSTEM DIVERSITY MATRIX

Haufler et al. (1996) introduced a process for implementing ecosystem management that utilizes a coarse filter approach to understanding ecological processes and maintaining biodiversity. A coarse filter attempts to provide a mix of ecological communities across a planning landscape that will sustain the viability of endemic species dependent on those systems. This process is being utilized by Boise Cascade's Idaho Ecosystem Management Project and provides the objectives for the development of landscape assessment tools and methodologies. The primary classification tool utilized in this process is the ecosystem diversity matrix (EDM). This tool presents a framework that combines an ecological classification system with successional trajectories, as influenced by historical disturbance regimes. Each cell in the matrix represents the coarse filter or range of ecological communities that can occur across a given landscape. The amount of each cell present on the landscape can be expressed quantitatively. Used in combination with a Geographic Information System (GIS), the ecological communities identified by the EDM can be expressed spatially as well. Within the overall process, the EDM is used to quantitatively express the historical range of conditions, in addition to existing conditions, to allow an evaluation of human-induced changes on the landscape both in terms of ecosystem processes and biodiversity objectives. Refer to Haufler et al. 1996 for a detailed description of the EDM in forested systems, as applied to the Idaho Southern Batholith landscape.

For any given landscape, several different ecosystem diversity matrices should be developed. For Idaho Southern Batholith landscape, four ecosystem diversity matrices or classifications are required to capture the full range of ecological communities present in that landscape:

1) Forested systems
2) Riparian/wetland
3) Shrub/grassland systems
4) Aquatic systems

This paper specifically addresses the development of the riparian/wetland EDM. The following sections describe the rationale for its framework, as well as a discussion of its application within an ecosystem management context.

RIPARIAN/WETLAND ECOSYSTEM DIVERSITY MATRIX

ECOLOGICAL CLASSIFICATION

An ecologically based classification system provides information on both biotic and abiotic features of a landscape, resulting in better integrated information for interpreting patterns and processes of landscape ecosystems (D.H. Van Lear 1991). An ecological classification delineates repeatable landscape units that exhibit predictable species assemblages and structures throughout their successional trajectory and when exposed to disturbance, both historical regimes as well as human-induced. Understanding the potential natural vegetation of a site and its preceding seral communities is critical to understanding the overall patterns and processes operating on a landscape. Ecological classification systems have been most extensively developed for forested systems; however, several recent classification systems and frameworks have begun to emphasize riparian and wetland systems (Maxwell et al. 1995, Hansen et al. 1995). Existing riparian and wetland classification systems typically have focused on existing vegetation, with little or no emphasis on site potential, successional pathways or historical disturbance regimes.

Portions of several existing riparian and wetland classification systems were used to establish an ecologically based classification framework for the riparian/wetland EDM. Those systems include the "Cowardin"

system (Cowardin et al. 1979), the Hydrogeomorphic Wetland Classification (HGM) system (Brinson 1993), and habitat typing (Daubenmire 1968). Recently, the Federal Geographic Data Committee has announced the adoption of the Cowardin system as the "standard" for all federal agencies in the identification, classification, and mapping of wetlands (Federal Geographic Data Committee 1996). The Cowardin system was developed by wetland ecologists and has been used extensively by wildlife professionals to classify wetland/riparian habitat for wildlife. For many, its strength lies in its ability to capture vegetation lifeform and structure in a meaningful way for describing habitat features (e.g., scrub-shrub, emergent, etc.). While the Cowardin system has long been recognized for its value in habitat assessment, it has also been described as deficient when applied to other disciplines. Most notably, it has been criticized for placing too much emphasis on the structure and species composition of the dominant plant community while providing little or no information on ecosystem function of riparian and wetland systems (Hansen et al. 1995, Brinson 1993) or important ecosystem processes such as successional trajectories or historical disturbance regimes. More recent classification systems have responded by emphasizing the physical features of riparian and wetland systems that sustain these systems on the landscape and consequently define their function within the ecosystem. The desire to characterize the function of riparian and wetland systems led the U.S. Army Corps of Engineers to develop the HGM system (Brinson 1993) for classifying riparian and wetland systems

While there is overlap between the HGM system and the Cowardin system, overall objectives differ in that the Cowardin system provides the framework for understanding the biogeographic distribution of plant and animal communities dependent on riparian and wetland systems, while the HGM provides the framework for understanding the influence of abiotic features on ecosystem function and processes of riparian and wetland systems. For this reason, agencies such as the U.S. Forest Service have recommended the adoption of the HGM system to provide information on riparian/wetland function, but combined with the Cowardin System to incorporate vegetation factors (J.R. Maxwell et al. 1995). We have taken a similar approach with the riparian/wetland EDM by attaching portions of the Cowardin system to the HGM system. However, we have also gone a step further and incorporated a link to adjacent upland vegetation, expressed as habitat type classes. We believe the combination of these three classification systems will meet the objectives for an ecologically based classification system in riparian and wetland systems by providing the framework for understanding ecosystem function and processes, as well as the distribution of biodiversity across a landscape. The following sections describe each of the three classification systems, how they are used and how they are expected to contribute to the overall objectives of the riparian/wetland EDM.

THE "COWARDIN" SYSTEM

The Cowardin (1979) classification system is used in the riparian/wetland EDM to describe the structure and species composition of the plant community. This information is important for understanding the diversity and distribution of vegetation communities as well as to characterize the habitat drivers for other biodiversity distribution across the planning landscape. The riparian/wetland EDM uses the Class level of the Cowardin system to describe the vegetation lifeform (Figure 2); i.e., the dominant structure of the vegetation. These features are usually visually recognizable and generally don't require the aid of environmental measurements to substantiate (Cowardin et al. 1979). For the Idaho Southern Batholith landscape, a slight modification in the Forested Class of the Cowardin system was deemed appropriate to describe potential successional pathways; consequently the forested

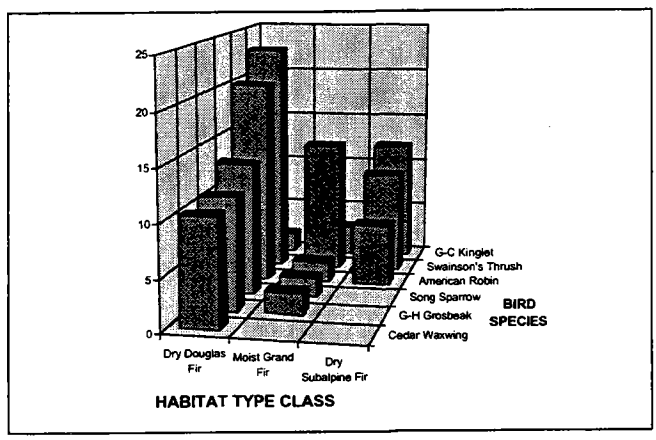

Figure 2. Example of songbird relative abundance as distributed among Habitat Type Classes within the Flat to Gentle Gradient Riparian Complex of the riparian/wetland Ecosystem Diversity Matrix (Sallabanks 1997).

class was divided into deciduous forests and coniferous forests at the Class level, rather than at the subclass level where it is normally differentiated. Incorporating the Cowardin system in the riparian/wetland EDM will also ensure the Federal Geographic Data Committees objectives for standardization can be met at the landscape level as well.

THE HYDROGEOMORPHIC WETLAND CLASSIFICATION SYSTEM

The formation of riparian and wetlands systems on a given landscape is primarily a function of the interaction between landform, geology, and hydrology occurring on a site (Winter and Woo 1990). To better understand this interaction, the HGM system emphasizes hydrologic and geomorphic (landform and geology) influences on riparian

and wetland processes and function (Brinson 1993). The HGM system does not consider the existing or potential vegetation on a site. The HGM strives to identify the hydrological function of riparian and wetland systems in the overall context of ecosystem function. By itself, the HGM system does not represent an ecological classification system which can identify a range of ecological conditions across a landscape. However, in combination with the Cowardin classification system, the objectives of an ecological classification can be met through the integration of abiotic and biotic factors. The HGM system as applied to the riparian/wetland system EDM, will identify the geomorphic and hydrological features that provide information on ecosystem function of riparian and wetland systems. Specifically, the riparian/wetland EDM utilized that portion of the HGM system that identifies a landscape (physiographic) setting for riparian and wetland systems, while also describing the general hydrological drivers for these sites as reflected in dominant ecosystem patterns for drainage and water storage. These physical drivers will influence the site potential for plant community development, which will in turn influence the distribution of animal diversity across the landscape. Furthermore, understanding the hydrological drivers in riparian and wetland systems is particularly important for understanding the influence of historical disturbance regimes on the species composition, structure, and successional trajectories of these ecological communities. Three geomorphic types and eight geomorphic subtypes were incorporated in the riparian/wetland EDM framework for the Idaho Southern Batholith landscape (Figure 2).

HABITAT TYPE CLASS

Habitat type classification is an ecologically based classification system that identifies land areas capable of supporting similar plant communities at late succession (Daubenmire 1968). A habitat type uses vegetation to represent a meaningful integration of environmental factors, both abiotic and biotic, affecting site potential for plant community development. Each habitat type supports a variety of disturbance-induced successional stages or seral communities, but because of the environmental influences operating on the site, succession will ultimately result in similar plant communities in late successional stages. It is important to note that although habitat typing uses late successional vegetation associations in its naming protocols, that does not mean that all units identified as a habitat type are in a late successional stage or need to be managed for a late successional stage (Hansen et al. 1995). The name simply indicates the potential vegetation of a site, but in reality a habitat type also provides information on the structure and species composition, both overstory and understory, of different successional stages. This information is critical to understanding the influence of historical disturbance regimes on ecological communities and in turn, the influences of the resulting landscape patterns on biodiversity distribution. Habitat typing has been most commonly applied to forested systems of the Rocky Mountain and intermountain regions of the West; and to a lesser extent, other regions of the country.

Habitat typing was used in the riparian/wetland EDM to provide an environmental gradient for understanding the landscape distribution of riparian and wetland systems. To accomplish this, the riparian/wetland EDM uses the adjacent upland zonal vegetation, expressed as habitat type classes, as an environmental gradient of climatic factors. Habitat types integrate the climatic influences of elevation, precipitation, slope, aspect, etc. Neither the HGM system nor the Cowardin system, by themselves or together, can accomplish this objective. Environmental factors influencing the distribution of upland vegetation across the landscape are also expected to influence the distribution of riparian and wetland systems as well. Preliminary field reconnaissance has supported the application of an environmental gradient in the riparian/wetland EDM framework. As an added benefit, stratifying the HGM/Cowardin classification on the adjacent upland habitat type classes also provides the link to the forested systems EDM and the grassland/shrub EDM, as well. The implications of the capability to integrate the EDMs will be discussed in a later section.

The riparian/wetland EDM framework presents the combined HGM/Cowardin system as the X-axis and habitat type classes as the Y-axis (Figure 2). The forested system EDM identified 11 habitat type classes with similar successional responses, evaluated in terms of species composition and structure, to historical disturbance regimes operating within that class (Haufler et al. 1996). To express an environmental gradient for purposes of the riparian/wetland EDM, these classes were further grouped to represent similar climatic influences on the adjacent riparian and wetland communities (R. Steele, forestry consultant, Boise, ID, pers. comm.). Grassland/shrub habitat type classes were also added, resulting in eight columns across the matrix.

As a side note, habitat typing was investigated as an ecological classification system for purposes of the riparian and wetland EDM. Hansen et al. (1995) provide a riparian and wetland classification that identifies both habitat types and community types (seral stages) for sites in Montana. However, developing a habitat type classification for riparian/wetland areas presents special challenges. The frequency of hydrological disturbance in these systems results in frequent changes in plant communities. In some instances, disturbance events can significantly alter the hydrology and/or soils on a site, resulting in an overall change in site potential or habitat type (Hansen et al. 1995). For this reason, we chose to develop a framework that will ultimately provide information on riparian and wetland habitat types but will not lose the information on the hydrological and geomorphic drivers

that help explain ecosystem function and processes operating in these systems.

HISTORICAL DISTURBANCE REGIMES

Little information is available on the range of ecological communities present in riparian and wetland systems as a result of historical disturbance regimes operating on a given landscape (LaRoe et al. 1995). The primary disturbance mechanism operating in riparian and wetland systems is hydrological storm events. The magnitude and impact of these events are further influenced by the geomorphology of a site. Hydrological events in riverine systems usually result in flowing water that can significantly influence the physical features of a site over time. Shoreline and depressional systems are less influenced by flowing water but are instead influenced by changing water levels, such as increases due to storm events or decreases due to drought. The framework for the riparian/wetland EDM captures the effects of disturbance on ecological communities by dividing each of the HGM/Cowardin wetland complexes into an early successional stage and late successional stage. The early successional category will represent only seral communities, and the late successional category will represent only late successional or habitat types, within each of the HGM/Cowardin lifeforms. This will provide an increased understanding of the successional trajectories within each of the HGM/Cowardin complexes and the potential consequences of disturbance on these ecological communities.

While hydrological events are the primary disturbance mechanisms in riparian and wetland systems, each landscape should be evaluated for additional historical disturbance regimes that influenced the temporal and spatial distribution of ecological communities. For the Idaho Southern Batholith landscape, beaver dams and fire were also important disturbance mechanisms historically. It is unclear at this time whether the riparian/wetland EDM framework as proposed will capture the influence of beaver dams on ecological communities. The framework currently assumes ecological communities established within a beaver dam complex will have similar ecological communities and successional trajectories as those found in the flat to gentle gradient riverine complex. No information is available at this time to support the delineation of a beaver dam wetland complex in the matrix; therefore, field assessments will be necessary to evaluate the validity of this assumption for the Idaho Southern Batholith landscape.

Understanding the effects of historical fire regimes on riparian and wetland systems presents a significant challenge, as fire suppression policies and intensive grazing have modified the effect of fire as it influenced these systems historically. Consequently, we have little knowledge of the effect of fire on the structure and species composition within riparian wetland systems, as well as the landscape patterns that may have resulted. However, using adjacent habitat type classes to represent an environmental gradient can also function to provide information on the frequency and intensity of historical fire in these adjacent upland systems. An understanding of the frequency, intensity, and habits of fire in the adjacent uplands will provide valuable insight into the potential effects of fire on the structure, species composition, and landscape patterns in riparian and wetland systems.

BIODIVERSITY RESEARCH

Understanding the distribution of biodiversity across a landscape requires that research be linked to a classification system that allows for: 1) quantification of existing conditions, 2) future projections of ecological communities, both temporally and spatially, and 3) a comparison of existing conditions with those produced under historical disturbance regimes (Haufler 1998). The EDM, when linked to a GIS, can accomplish all three of these biodiversity research requirements. As stated previously, the EDM functions as a coarse filter for biodiversity distribution by identifying the range of ecological communities that can be present on a landscape. In so doing, the EDM can represent the range of conditions endemic species have evolved with and adapted to within a 200- to 400-year time frame (Morgan et al. 1994). To understand the influence of both natural and human-induced impacts on the distribution of biodiversity within a landscape, it is critical that we are able to use the EDM to quantify existing conditions, as well as quantify the range of historical conditions. The riparian/wetland EDM will allow a comparison of this nature to be accomplished on a given landscape.

To describe the distribution of biodiversity across a landscape, relative abundance measures can be obtained for individual species having small home ranges, by conducting field censuses on ecological units of the EDM (Haufler 1998). The distribution and abundance of species with large home ranges can be predicted using habitat suitability models that use habitat features measured for each ecological unit in the EDM (Haufler et al. 1996). The forested systems EDM has been used for the past 3 years to document forest songbird distribution and abundance within the Idaho Southern Batholith landscape (Sallabanks 1997). In addition, we have also conducted some preliminary research to document songbird distribution and abundance using the riparian/wetland EDM. Specifically, bird communities were sampled within the Dry Douglas-Fir, Cool-Moist Grand Fir, and Dry Subalpine Fir Habitat Type Classes of the Flat to Gentle Gradient Wetland Complex. Preliminary results indicate avian community composition differed considerably between riparian and non-riparian sites, as well as among habitat type classes within riparian sites (Figure 3).

Although preliminary, these data indicate that the riparian/wetland EDM can capture the complexity of ecological communities across a landscape and allow us to quantify the distribution of biodiversity as well.

INTEGRATION OF ECOSYSTEM CLASSIFICATION SYSTEMS

The lack of an ecosystem perspective on the interaction of terrestrial, riparian/wetland, and aquatic systems severely limits our understanding of the ecological relationships necessary to maintain or restore ecosystem processes and biodiversity across a landscape. Riparian and wetland systems represent the ecological interface between the terrestrial and aquatic systems, thereby functioning as the critical component of an integrated ecosystem classification system. The EDM concept recognizes the need for an ecosystem perspective; consequently it incorporates a mechanism for linking all matrices required for a landscape. The mechanism incorporated in the four matrices being developed for the Idaho Southern Batholith landscape is an environmental gradient expressed as habitat type classes. Through this environmental gradient, we will be able to evaluate and compare the results of ecological studies across terrestrial, riparian/wetland, and aquatic systems. We will gain an understanding of the ecological relationships necessary to maintain or restore ecosystem processes and biodiversity across a landscape. Recently, the riparian/wetland EDM was used by the Lowman District of the Boise National Forest to evaluate the potential riparian vegetation associated with bull trout (*Salvelinus confluentus*) spawning habitat within the Deadwood landscape (Steele 1997). Results of the analysis indicate a surprising association of bull trout spawning sites with the environmental gradient axis of the EDM. All known bull trout spawning sites were located adjacent to the Persistent Lodgepole Pine Habitat Type Class of the riparian/wetland EDM. Persistent lodgepole pine (*Pinus contorta*) is usually found in frost pockets along drainage systems (Steele 1981), and bull trout are usually associated with cold waters (Shepard et al. 1984); therefore, from an ecosystem perspective this association may not be surprising. These are the types of relationships an integrated ecosystem classification will capture, thereby increasing our knowledge of the complex relationship between ecological communities and their associated biodiversity.

CONCLUSIONS

Thus, the riparian/wetland EDM is one of four EDMs that, when used in combination, provide a coarse filter framework for implementing ecosystem management. This coarse filter can be used to quantify the amounts and distributions of the full complex of ecological units that comprise the planning landscape at present, historically, and in the future. The riparian/wetland EDM is designed to have a sufficient degree of resolution to describe the range of ecological communities in a way that will allow the distribution of the full array of biodiversity to be quantified and incorporated into the planning process. At the same time, the EDM approach also strives to maintain a reasonable level of complexity in its classification framework to ensure feasible application for both research and management implementation.

While we believe the framework presented in the riparian/wetland EDM holds considerable promise as a coarse filter for meeting ecosystem management objectives, it is important to note that at present it has had only limited testing in the field. Considerably more work will be required to describe the plant and animal communities associated with each ecological unit in the matrix. Similarly, the relationships among the adjacent uplands and aquatic communities to the riparian/wetland ecological units require additional research. We have chosen to present the riparian/wetland EDM early in its development to provide an example of the thought processes that will be required to utilize and apply existing information at the ecosystem level, as well as to provide an example of the potential information that can be gained from integrated classification systems regarding ecosystem processes and relationships.

ACKNOWLEDGMENTS

Robert Steele conducted the preliminary field reconnaissance to aid in the development of the framework for the Idaho Southern Batholith landscape. He also provided invaluable expertise with expressing the environmental gradient in terms of the adjacent habitat type classes. Paul Hansen and Robert Pfister of the University of Montana also provided constructive input on the EDM framework. Rick Hauer, Flathead Lake Biological Station, provided valuable information on the application of the HGM system in the Intermountain Region.

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RESEARCH TO SUPPORT SUSTAINABLE WATERSHED MANAGEMENT

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ABSTRACT

Research into physical and biological processes to support sustainable resource management is facilitated by dedicated landscape units, such as experimental forests and research watersheds, which are representative of the larger ecoregion and are available for repeated, long-term measurement and analysis. Two established watershed research programs conducted in upland landscapes receiving similar total annual precipitation, each dominated by seasonal snowfall, but with very different soils, climate, vegetation, land use, and hydrologic and sediment yield regimes, provide examples of such dedicated landscape units. The 234 km^2 Reynolds Creek Experimental Watershed was established in the Owyhee Mountains of southwestern Idaho (43°15' N, 116°45' W) in 1960 to study watershed hydrology in semiarid uplands of the interior Pacific Northwest. The 104 km^2 Caribou-Poker Creeks Research Watershed was established in 1969 (and recently linked with Bonanza Creek Experimental Forest) for hydrologic and ecosystem research in the discontinuous-permafrost Yukon-Tanana Uplands of central Alaska (64°10' N, 147°30' W). Research at both sites has addressed basic climatic and hydrologic processes, plant community structure, biodiversity, and commodity production. These research watersheds, which are incorporated into national and international cooperative programs, offer: a landscape-scale ("real world") context for plot studies; an interdisciplinary base of research and monitoring over years to decades; long-term annotated, reviewed data bases for hydrologic, stream quality, and climatic parameters; careful site documentation including geology, soils, vegetation, and land use history; complementary biological and physical process research; a sustained institutional commitment which may be difficult to achieve for isolated plot studies; and opportunities for collaborative long-term research and monitoring in support of sustainable resource management at watershed and regional scales.

Key words: watershed, hydrology, research, rangelands, boreal forest, sediment, biodiversity, Pacific Northwest, Idaho, Alaska, permafrost

INTRODUCTION

The need for long-term, sustained observation and research programs to address regional and global environmental questions has been widely described (Callahan 1984, Likens 1989, Brechtel and Fuhrer 1994). Burt (1994) stressed that long-term monitoring "...if well designed and properly maintained, can provide important evidence of environmental change and stimulus to further experimental research," and can provide the initial data with which meaningful research hypotheses can be formulated. Sustained measurements at landscape-scale field sites offer the potential for establishing "baselines" of selected parameters such as precipitation, streamflow, air and ground temperature, or water quality, and with those baselines evaluating both "normal" and extreme, infrequent events. Management of watershed systems for sustained production of multiple commodity and non-commodity values is bolstered by research into the physical, biological, and social attributes and processes of those systems.

Hydrologically defined landscape units (drainage basins, catchments, or watersheds) can provide appropriate sites for process research and baseline monitoring, and furnish a framework for linkage of terrestrial and aquatic systems in interdisciplinary research (Likens et al. 1977, Bormann and Likens 1979, Naiman and Sedell 1981, Slaughter et al. 1995). Long-term hydrologic measurement programs involving landscape-scale drainage basins or watersheds have been instituted to obtain information from different sectors of nations such as the United States (Cobb and Biesecker 1971), or of discrete regions such as the circumpolar high latitude lands (Danish Society for Arctic Technology, 1988) or northern Europe (Gustard 1994). Knowledge of hydrologic processes and rates is essential to understanding physical and biological processes and relationships at individual sites, on integrated landscapes, and within whole ecosystems (Likens 1983,

Swank and Crossley 1988). Watersheds include **ecotones**, zones of change in system properties and often zones of high diversity, which may be critical to understanding some aspects of ecosystem (di Castri et al. 1988). One such ecotone, the streamside riparian zone, is particularly highlighted in current western resource management debates (e.g., Masters et al. 1996).

This paper offers examples of two watershed research programs (Figure 1), widely separated but similar in concept and operation. Each conducts hydrologic and natural resources research in ecosystems which are sensitive to management practices and to possible climate change, and which are coming under increasing pressures for sustainable management to achieve diverse objectives.

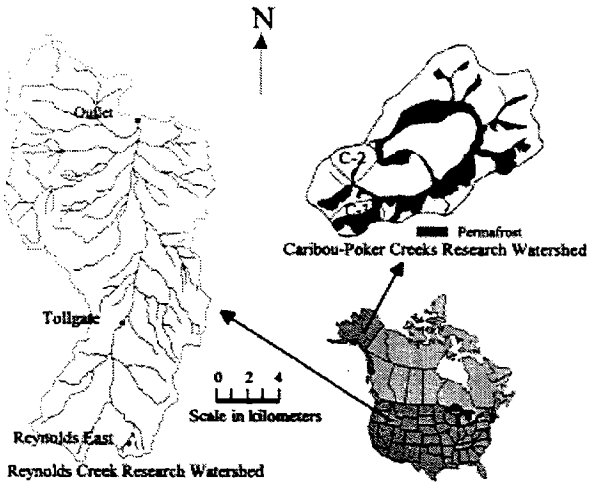

Figure 1. Reynolds Creek Experimental Watershed and Caribou-Poker Creeks Research Watershed.

Pacific Northwest Rangeland: Reynolds Creek Experimental Watershed

Reynolds Creek Experimental Watershed (RCEW) was established in 1960 as a field laboratory to address issues of water supply, water quality, and rangeland hydrology in the semiarid rangelands (and associated high-elevation woodlands) of the interior Pacific Northwest. The 234 km^2 watershed is located in the north flank of the Owyhee Mountains in southwestern Idaho, approximately 80 km southwest of Boise, Idaho. Detailed mapping of the geology of the watershed was accomplished by McIntyre (1972).

The USDA-Natural Resources Conservation Service (formerly Soil Conservation Service) completed a soil survey for RCEW in 1966 which is currently being updated. The vegetation in the watershed has been completely mapped (Stephenson 1977). Reynolds Creek is a third-order perennial stream that ranges in elevation from 1,100 m to 2,250 m, and drains north to the Snake River.

Precipitation varies from about 23 cm at the northern lower elevations, to over 100 cm in the higher regions at the southern and southwestern watershed boundaries (Figure 2). At these upper elevations about three-fourths of the annual precipitation occurs as snowfall (Hanson and Johnson 1993). Plant communities at lower elevations are typical of the Great Basin Desert, while forest and alpine plant communities may be found at the highest elevations. About 77% of the watershed is federal or state lands, with the remainder under private ownership. The primary land use is livestock grazing with some irrigated fields along the creek at the lower elevations, and some timber harvest in high-elevation forests. RCEW is increasingly utilized for summer and winter outdoor recreation.

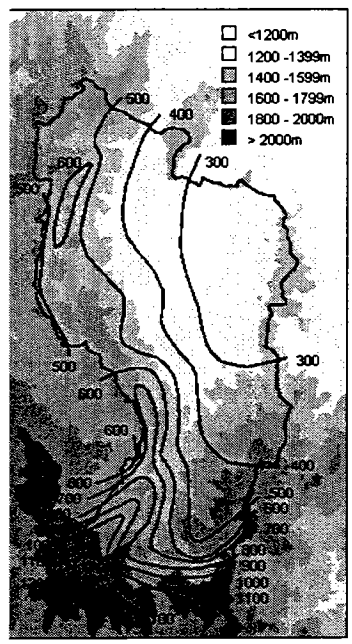

Figure 2. Distribution of elevation and mean annual precipitation, Reynolds Creek Experimental Watershed, Idaho.

RCEW lies in an eroded structural basin, with late Tertiary volcanic and sedimentary rocks overlying Cretaceous granitic basement rocks. Soils range from shallow desertic soils at lower elevations to relatively deep organic soils in higher regions, the latter typically occupied by forest species. The primary vegetation cover types in RCEW are Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis*); mountain big sagebrush (*Artemisia tridentata* subsp. *vesyana*); low sagebrush (*Artemisia arbuscula*); curleaf mountain mahogany (*Cercocarpus ledifolius*); bitterbrush (*Purshia tridentata*); quaking aspen (*Populus tremuloides*) woodland; bluebunch wheatgrass (*Pseudoroegneria spicata*)/ Sandberg bluegrass (*Poa sandbergii*); Idaho fescue (*Festuca idahoensis*)/bluebunch wheatgrass; salt desert shrub; alpine rangeland; subalpine fir (*Abies lasiocarpa*);

Douglas-fir (*Pseudotsuga menziesii*); and riparian communities.

Hydrologic research and monitoring have been conducted since the early 1960s. There has been strong research emphasis on precipitation, climate (Hanson et al. 1980; Hanson 1989), seasonal snowpack accumulation and hydrologic regime (Wilcox et al. 1989), seasonally frozen soils (Burgess and Hanson 1979; Burton et al. 1990; Hanson and Flerchinger 1990; Seyfried et al. 1990), and on rangeland hydrology, streamflow, soil erosion, and stream sediment processes (Johnson and Gordon 1988; Blackburn et al. 1990; Pierson et al. 1994; Spaeth et al. 1994). Detailed meteorological measurements are collected hourly at three sites (low, middle, and high elevation). Continuous precipitation data are collected at 16 dual-gauge sites, complemented by seven snow courses and one recording snow pillow. Streamflow is continuously monitored at nine locations. Precipitation chemistry is monitored weekly at a National Atmospheric Deposition Program site in the Reynolds Creek valley.

Subarctic Boreal Forest: Caribou-Poker Creeks Research Watershed and Bonanza Creek Experimental Forest

A northern boreal forest ecosystem monitoring site is in operation at 65°N latitude in the discontinuous-permafrost Yukon-Tanana Uplands of central Alaska. The site is (Figure 3) comprised of Caribou-Poker Creeks Research Watershed (CPCRW) and Bonanza Creek Experimental Forest (BCEF) (Slaughter et al. 1995).

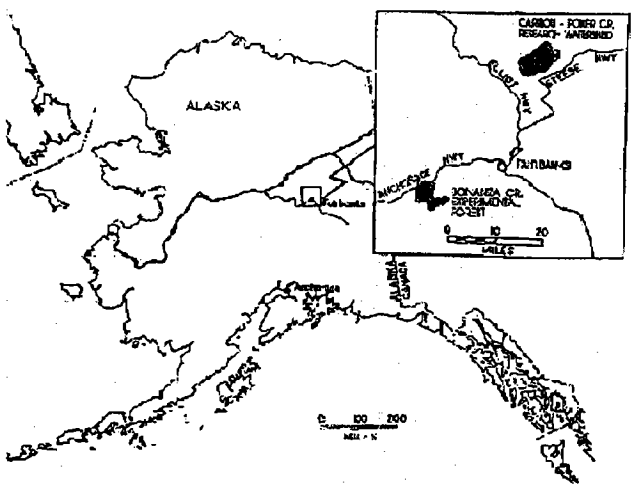

Figure 3. Caribou-Poker Creeks Research Watershed and Bonanza Creek Experimental Forest, Alaska.

Caribou-Poker Creeks Research Watershed, 40 km^2 north of Fairbanks, is a 104-km^2 Experimental Ecological Reserve comprised of a complete catchment/stream system continuum from headwaters (first-order basins) to fourth-order stream, encompassing permafrost-underlain and permafrost-free ecosystems. CPCRW objectives are to develop an understanding of hydrologic, climatologic, and environmental relationships in taiga ecosystems, to support catchment-scale research on effects of resource management practices on these relationships, and to support multi-disciplinary long-term environmental research and monitoring (Haugen et al. 1982). CPCRW research includes headwaters hydrology of discontinuous-permafrost landscapes, stream quality and aquatic ecology, application of stream continuum concepts to high-latitude stream systems, permafrost temperature regime, thermokarst development and pingo degradation, and forest management practices in the taiga (Oswood et al. 1989, Lawson et al. 1991, Hinkel et al. 1993, Slaughter and Hartzmann 1993, Irons et al. 1993). Bonanza Creek Experimental Forest is located 30 km west of Fairbanks, on the floodplain (120 m) and adjacent low ridges (up to 450 m) immediately north of the Tanana River. The 50-km^2 BCEF has a 35-year history of research into plant ecology, silviculture and forest management, and is the site for a Long-Term Ecological Research (LTER) investigation into forest succession on floodplain and uplands (Van Cleve and Martin 1991). Current LTER research in BCEF addresses vegetation succession in the floodplains and uplands, herbivory, and resource availability to specific vegetation communities in relation to climate, nutrient availability, and biogeochemical processes. The BCEF long-term ecological research program was recently linked with CPCRW research.

CPCRW/BCEF is in the Tanana River basin, in the southern portion of the Yukon-Tanana Uplands. This region of uplifted Precambrian Birch Creek schist is overlain by a mantle of loess (up to 200 m thick at lower elevations immediately north of the Tanana River, and as little as 50 cm thick at higher elevations and on north-aspect slopes of CPCRW) derived from glacial outwash floodplains to the south. The strongly continental climate of interior Alaska is characterized by long, cold winters and short, warm summers with extreme seasonal fluctuation in day length (Slaughter and Viereck, 1986). CPCRW/BCEF lies in the zone of discontinuous permafrost (perennially frozen ground); south-facing slopes are generally free from permafrost, while poorly-drained valleys and north-facing slopes are underlain by frozen ground at shallow depth. Permafrost thickness can exceed 100 m in this region.

The vegetation of CPCRW/BCEF is typical of Alaska's northern boreal forest and reflects the interactions of topography, soils, slope, aspect, elevation, fire history, and flooding and sediment deposition on lowlands (Viereck et al. 1986; Jorgenson et al. in press). North slopes are characterized by black spruce (*Picea mariana*), ericaceous shrubs, and a thick feather moss/sphagnum moss/lichen ground cover and deep organic matter layer; south-facing slopes support forest stands of varying age classes of aspen (*Populus tremuloides*), birch (*Betula*

papyrifera) and lesser amounts of white spruce (*Picea glauca*) and black spruce. Alder (*Alnus crispa*) is present and locally important throughout the watershed. Valley floors are generally poorly drained and underlain by permafrost, and support dense stands of dwarf birch (*Betula glandulosa*), blueberry (*Vaccinium uliginosum*), willows (*Salix* spp.) and associated shrubs and forbs. The stream valleys and lower slopes also support sedges, fen, and *Eriophorum* tussock communities.

The composite CPCRW/BCEF site offers a suite of environmental settings (Figure 4) ranging from recently colonized bars of the Tanana River floodplain at 120 m elevation, through the foothills and valleys of the Yukon-Tanana Uplands, to subalpine and alpine tundra on the highest ridges of CPCRW at over 820 m elevation. Climate and hydrologic monitoring is accomplished at 22 sites ranging from floodplain (BCEF) to treeline (CPCRW). Seasonal snowpack is measured monthly at four USDA-Natural Resources Conservation Service snow courses, and monitored continuously with two recording snow pillow installations. Streamflow in CPCRW is measured with prefabricated Parshall flumes installed in four first-order streams, and with natural channel controls at three downstream sites. Long-term hydrometeorological monitoring is complemented by intensive process research conducted under the Long-Term Ecological Research (LTER) program at BCEF. The northernmost National Atmospheric Deposition Program station in the U.S. is operated in CPCRW to monitor precipitation constituents.

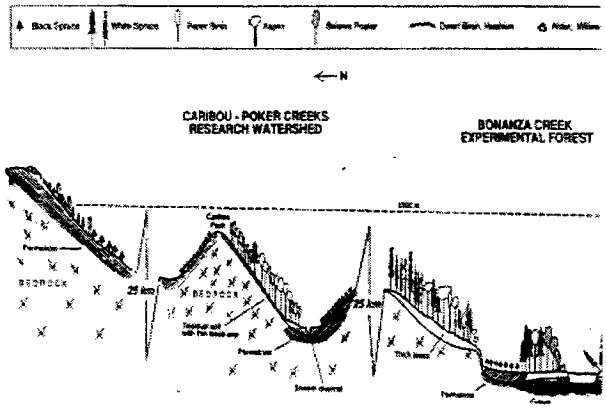

Figure 4. Landscape toposequence, Caribou-Poker Creeks Research Watershed and Bonanza Creek Experimental Forest.

Water quality of streams in CPCRW has been monitored to determine seasonal and annual nutrient, metals, and sediment loadings. The CPCRW/BCEF research complex is entirely on public land, managed under renewable 50-year agreements with the State of Alaska, Department of Natural Resources.

HYDROLOGIC RESEARCH

Hydrologic regime can vary markedly with landscape physiography, climate, vegetation, and land use. Understanding hydrologic processes, rates, and relationships is a prerequisite to developing and implementing comprehensive watershed management programs. The long-term programs at RCEW and CPCRW support developing that understanding, and characterizing temporal and spatial hydrologic variability in their respective settings.

Precipitation varies with elevation, topographic position, and time. This is documented in RCEW, where higher elevation sites in the southwestern sector of the basin receive the most annual precipitation (Figure 2), while lower sites are much drier. Timing of precipitation within any year also varies with location; high-elevation sites get most of their precipitation in winter, predominantly as snow, while drier low-elevation areas have more evenly distributed precipitation which is normally rain even during winter. The value of long-term records is evident when looking at inter-annual variability; wide variation in annual precipitation is evident over the period of record at RCEW (Figure 5). This is similarly evident in CPCRW/BCEF, where, for example, seasonal snow accumulation (Figure 6) varied widely over 3 decades.

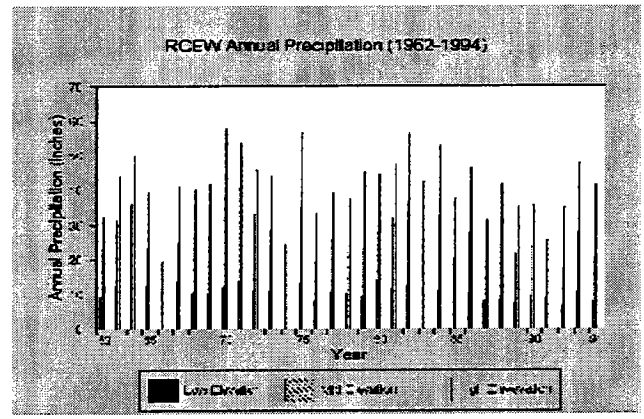

Figure 5. Annual precipitation at three locations in Reynolds Creek Experimental Watershed, 1962-1994.

Streamflow from precipitation and snowmelt is similarly variable. The RCEW record shows marked differences in runoff pattern from high-elevation (Reynolds Mountain) to mid-elevation (Tollgate) to low-elevation (Outlet) sites (Figure 7); marked year-to-year variation in runoff is evident, obviously in response to variation in precipitation and snowmelt. Similar year-to-year variability is evident in streamflow at CPCRW (Figure 8).

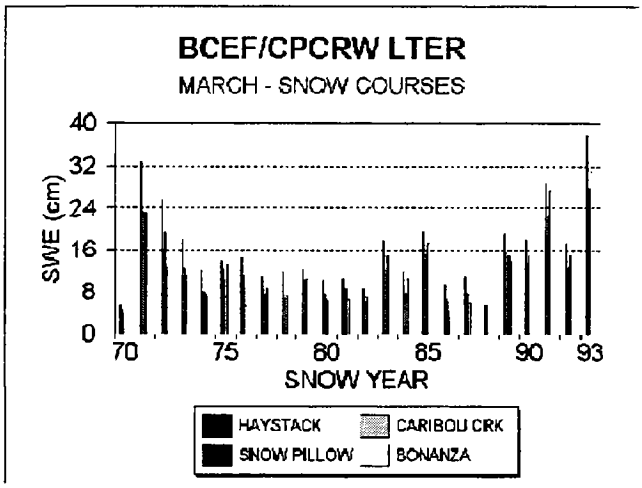

Figure 6. Maximum annual snow accumulation, Caribou-Poker Creeks Research Watershed and Bonanza Creek Experimental Forest, 1970-1993.

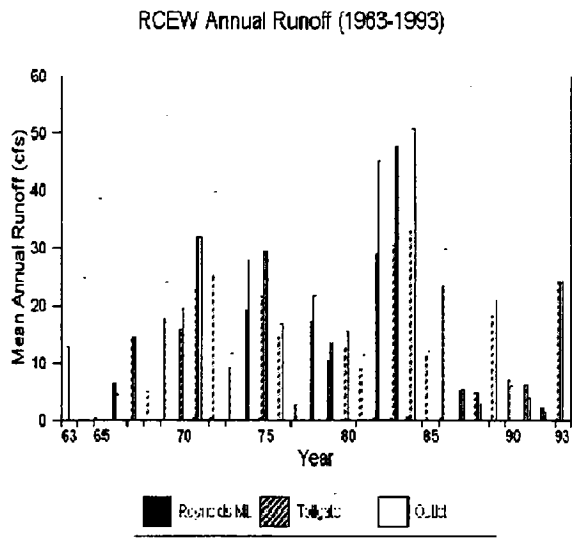

Figure 7. Annual runoff, three locations in Reynolds Creek Experimental Watershed.

A strong contrast in local climate between north-aspect (permafrost-underlain) and south-aspect (permafrost-free) catchments at CPCRW (Figures 1, 4) is reflected in streamflow regime. Contrasting first-order catchments (C-2, 5.2 km^2, south aspect, 3.5% permafrost, vs C-3, 4.5 km^2, northeast aspect, 53% permafrost) differ primarily in the presence of permafrost, which is a function of latitude, aspect, and topographic position and which strongly affects vegetation (Viereck et al. 1986) and hydrologic regime (Dingman 1975; Slaughter et al. 1983). Permafrost can act as an aquaclude, restricting aquifer recharge and discharge; this effect becomes more pronounced with increasing proportion of permafrost in a catchment. Permafrost-underlain slopes yield water more rapidly to streamflow than do permafrost-free slopes, contributing to more "flashy" storm hydrographs: permafrost-dominated catchments have higher unit-area peak flows, lower base flows, and steeper hydrograph recessions than nearby permafrost-free catchments, as reflected (Figure 9) in hydrographs and flow-duration curves (Slaughter et al. 1983).

MANAGEMENT APPLICATIONS FROM RESEARCH

More complete understanding of hydrologic processes and relationships should enhance the ability to develop improved management plans and prescriptions for specific watershed settings. Examples from RCEW and CPCRW/BCEF illustrate a range of research applications.

Modeling: Resource management models are increasingly used in problem analysis and decision development. Testing and validation of hydrologic models has been a major effort at RCEW; research watershed data are being utilized to validate and refine the SHAW model for heat and water flux (Flerchinger et al. 1990) in upland watersheds, in spatial application of the GEM stochastic climate generation model for mountainous terrain (Hanson and Johnson 1997), and in development and validation of resource management models (Wight 1994). The SHE hydrologic model was applied to an upland subbasin of RCEW (Bathurst and Cooley 1996), and new distributed hydrologic process models are currently being developed and tested utilizing RCEW data bases (Tarboton et al. 1996). There are current plans to parameterize and apply the HBV hydrologic model at CPCRW (Hinzman, personal communication 1997).

Extreme events: While patterns of precipitation, snowmelt, and runoff are generally known, the hydrology of infrequent extreme events such as the February 1996 Pacific Northwest storm and resulting flood is poorly documented. Extreme events can be either localized or regional. RCEW has experienced regional drought, localized convective storms, and regional storms and floods, including the 1964/65 winter storms which affected the entire Pacific Northwest (Johnson 1965). In contrast to the 1964/65 storms, RCEW and southwestern Idaho were spared the direct effects of the February 1996 storm which struck much of Oregon, Washington, and northern Idaho. Observations from selected sites in RCEW were used to characterize the February 1996 event (Slaughter et al. in press). The February 1996 flow at RCEW was a modest hydrologic event, with an estimated return period (log-Pearson Type III) of 1.9 years.

Three decades earlier, major storms of December 1964 and January 1965 directly impacted RCEW and produced severe flooding (Johnson 1965). During the 3 days 21-24 December 1964, approximately 91 mm (3.59 in) of precipitation fell over the entire RCEW (which

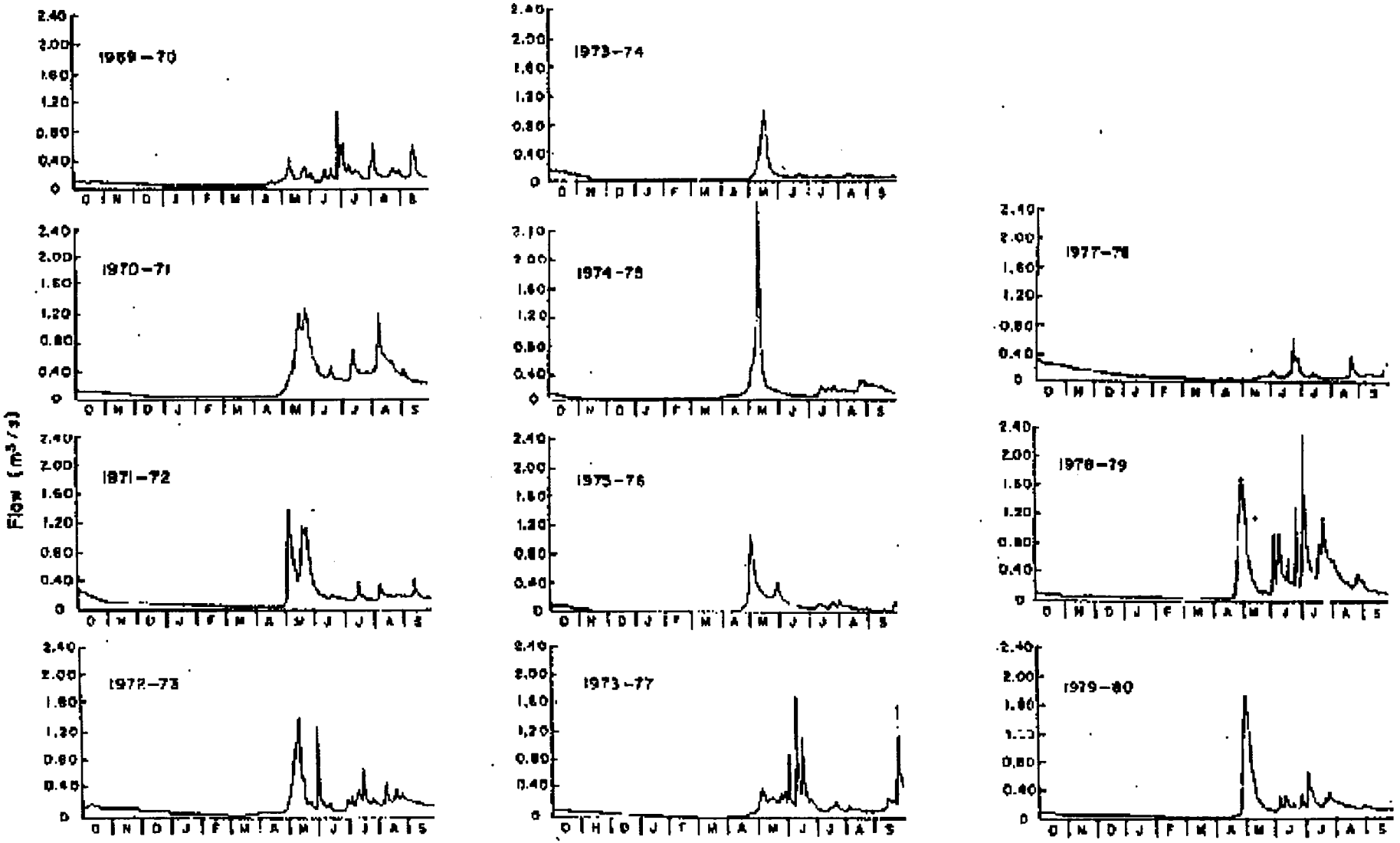

Figure 8. Inter-annual flow variability, Caribou Creek, 1969-1980.

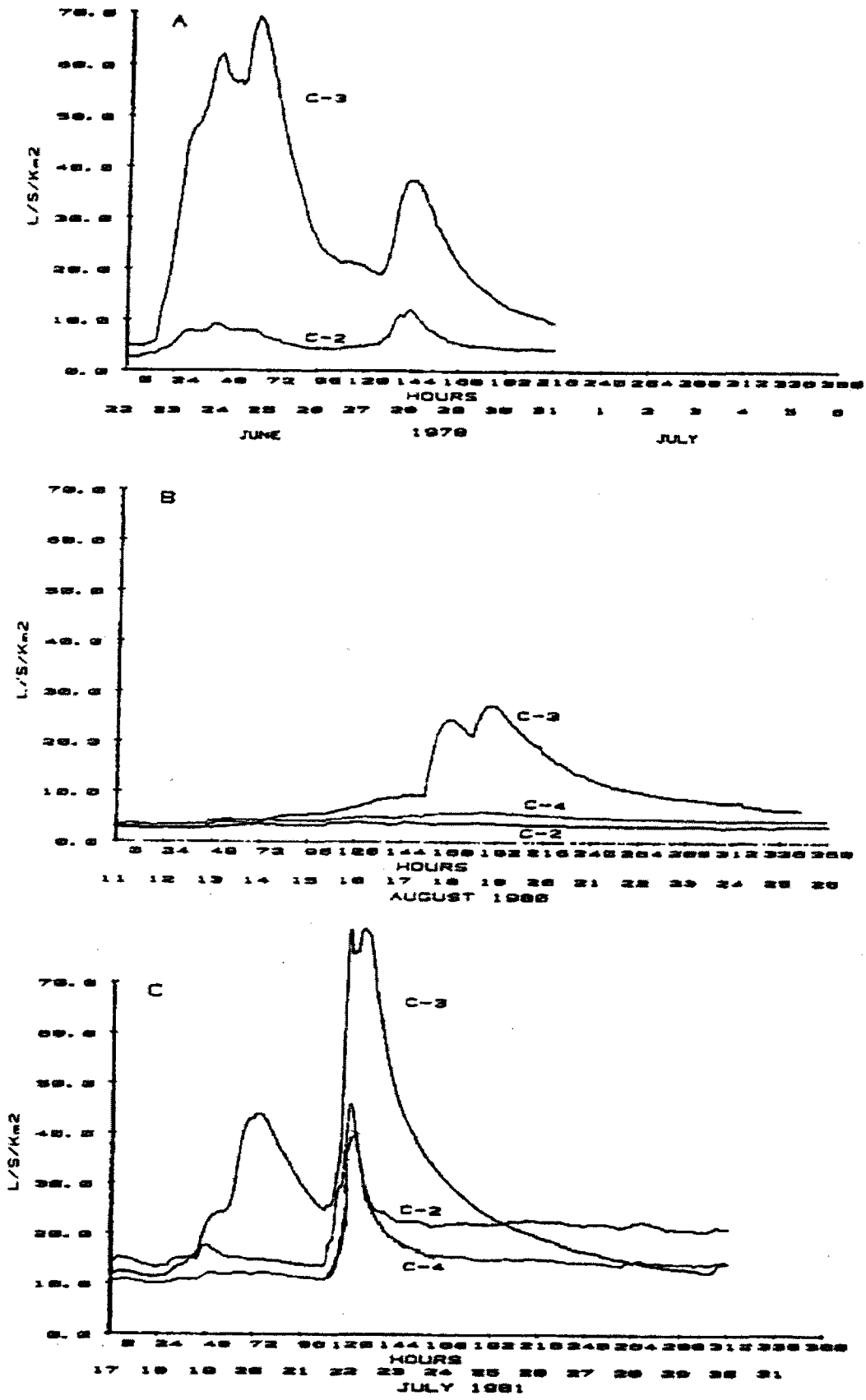

FIgure 9. Comparative hydrographs for permafrost-affected (C-3) and permafrost-free (C-2) basins, CPCRW.

already had an existing snowpack of 6 mm water snow water equivalent). The runoff produced from precipitation and concurrent snowmelt was approximately one-third of the total 1964 runoff volume from RCEW; the peak discharge at the Outlet Weir was 109 m^3/sec (3,850 cfs). The December 1964 flow was the highest which has been measured at RCEW since establishment of the research program, and had an estimated return period of 72 years.

Coupling this knowledge of the 1964/65 storm response at RCEW with information about the February 1996 storm allows constructing an instructive "worst case" scenario. During the first 2 weeks of February 1996 the Blue Mountains of northeastern Oregon/southeastern Washington and the high elevation lands of north-central Idaho received very high precipitation at the time that RCEW received very little. We made the simplifying assumptions (1) that actual precipitation measured at these locations was a reasonable indication of that which could have been received in the Owyhee Mountains and RCEW, had the storm track shifted slightly southwest (as actually happened in 1964/65), and (2) that the ratio of peak streamflow to 3-day mean streamflow for the storm was 5.2, the same ratio as was actually observed at RCEW in the December 1964 event. Sites selected, and precipitation for the period 4-10 February 1996, were: Elgin, Oregon (72 mm), in the Grande Ronde valley at elevation 808 m (2,650 ft); High Ridge, Oregon (145 mm), in the Blue Mountains at 1,518 m (4,980 ft) elevation; Brundage Reservoir, Idaho (57 mm), elevation 1,920 m (6,300 ft); Elk Butte, Idaho (269 mm), elevation 1,692 m (5,550 ft); and West Branch, Idaho (193 mm), elevation 1,695 m (5,560 ft).

The "Elgin" scenario simply assumed that the rainfall reported at Elgin, Oregon, during the period 4-10 February 1996 (72 mm, 2.84 in) would have fallen over RCEW and been available for streamflow. Including complete melt of the snowpack actually present at RCEW in February 1996 with the Elgin precipitation yields an estimate that the RCEW flow would have peaked at 113 m^3/sec (4,006 cfs), higher than the record December 1964 peak flow. Combining the Elk Butte February 1996 precipitation with the RCEW snow cover melt yields an estimated potential maximum flow for Reynolds Creek at the Outlet Weir of 315 m^3/sec (11,132 cfs), nearly three times greater than the extreme flow experienced in 1964, which was considered a very large flood.

The fact that February 1996 was a "non-flood" event in southwestern Idaho does not lessen its hydrologic interest. Permanent research installations such as RCEW will inevitably be impacted by some events and missed by others. In this instance, knowledge of the watershed's physical and hydrologic characteristics and ongoing hydrologic monitoring concurrent with the nearby storm allows estimation of potential consequences of this and other events. A minor southeast shift of the February 1996 storm track could have resulted in record high streamflows in southwestern Idaho. Understanding this risk can be useful in planning emergency preparedness, flood control, and water supply strategies and advancing knowledge of hydrologic regimes of mountainous areas.

Sediment regime: Fluvial erosion and sediment production is a major concern in natural resource management. The National Research Council (1994) recently identified control of erosion and maintenance of the soil resource as key to managing and sustaining overall rangeland site productivity. Extensive research on sediment production, transport, and yield has been accomplished in research watersheds (e.g., Leaf 1966, Borges and Bordas 1988, Wicks et al. 1988, Slaughter and Aldrich 1989, Renard et al. 1991). Nevertheless, Shen (1991) suggested that watershed sediment yield is "...perhaps, the most difficult problem facing us in the field of sedimentation...," due to complex interactions of heterogenous landscape, soils, precipitation, climate, and management conditions. Suspended sediment yields at RCEW and CPCRW were summarized by Slaughter et al. (1996).

Reynolds Creek Experimental Watershed: The primary objective of early sediment measurements at RCEW was to determine sediment yields from semiarid rangeland watersheds, emphasizing storm runoff. Johnson and Hanson (1976) reported that average sediment yields from RCEW and individual subwatersheds ranged from 1.14 to 1.9 tonnes/ha/year. Unit-area sediment yield from upland source areas was only one-third or less of that measured from the larger downstream watersheds. Most sediment is produced by a small percentage of yearly runoff, and (contrary to expectations) sediment concentrations and unit-area sediment yield appeared to increase with drainage area, apparently due to streambank erosion and channel flushing.

Major frontal rainfall events occasionally produce runoff and sediment from the entire RCEW, but most runoff events at lower elevations are caused by high intensity rainstorms, often on frozen soil, while runoff events at higher elevations are caused by snowmelt. Sediment measured at sites below 1,400 m msl was produced mainly from rainfall events, while snowmelt-runoff was responsible for most sediment production at higher elevations; sediment production in drought years was negligible, while flood years produced high sediment yields (Johnson and Gordon 1988). Sediment yields were more than 10 times higher in wet years than in dry years, and about 90 percent of average yearly yield at the RCEW Outlet occurred in winter, during January through March.

The spatially and temporally variable nature of sediment yield has been underscored by recent research. Total annual suspended sediment yields from the Reynolds Mountain, Tollgate, and the entire RCEW at Outlet vary widely, with high-year yields being 10 to 200 times greater than yields in low years (Figure 10; Reynolds Mountain

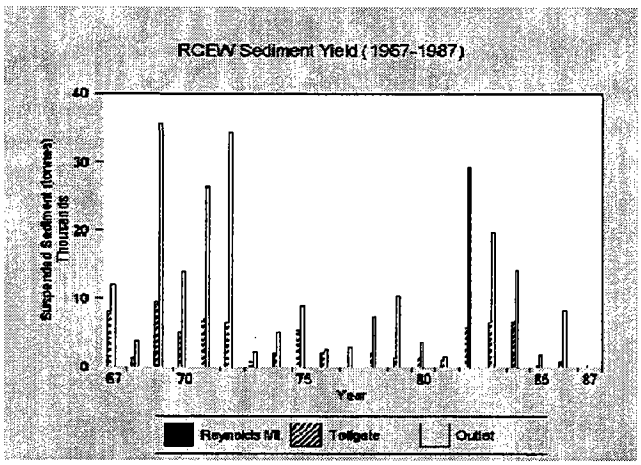

Figure 10. Annual sediment yield measured at three sections in Reynolds Creek Experimental Watershed.

sediment yield is too low to be seen at the scale used). Years of high or low sediment production do not necessarily correspond among these sites. High sediment yields from the smaller upstream catchment are often overshadowed by or diluted by contributions from other sectors of the larger watershed.

While earlier short-term (8 to 10 years) studies had suggested that up to 90% of annual sediment yield occurred in the January-March period, the longer 21-year record indicates that only 72% of annual sediment is yielded during this period.

Over 21 years of record, suspended sediment yield averaged 0.5, 0.66, and 0.20 tonnes/ha/yr for RCEW at Outlet, Tollgate, and Reynolds Mountain, respectively. In the lower portions of RCEW, rain on snow or frozen soil often produces the major events. While summer rain events do occur and can produce significant runoff and sediment production at higher elevations, the predominant headwaters runoff and sediment yield come from spring snowmelt.

Caribou-Poker Creeks Research Watershed: Streamflow and suspended sediment have been monitored in CPCRW since the mid-1970s, during the ice-free summer streamflow season following spring ice breakup and snowmelt runoff. Acquisition of data during spring breakup was hindered by extensive aufeis accumulation at the gauges (Slaughter and Benson 1986). Suspended sediment samples taken within the flumes utilize both weekly grab samples and automated pumped samplers set to obtain hourly or 6-hourly storm samples. The influence of permafrost is reflected in sediment regime of upland catchments at CPCRW (Slaughter and Collins 1981). Summer-season sediment yields from first-order basins with varying influence of permafrost over 3 years, selected to represent low flows (1978, 1980) and high flows (1981), are given in Table 1. Sediment yield during relatively dry years is low from both permafrost-dominated and permafrost-free basins, averaging less than 0.4 g $m^{-3}km^{-2}day^{-1}$ in both cases. During years of high flow such as 1981 the effects of permafrost are evident in accelerated sediment yield. C-3 (permafrost-dominated) yielded 11.2 kg $km^{-2}day^{-1}$ *vs* 3.0 kg $km^{-2}day^{-1}$ from the nearly permafrost-free C-2 basin (Slaughter et al. 1983). The corresponding seasonal sediment production totals were ca. 5,600 kg and 2,200 kg, respectively. The sediment values reported do not include the primary hydrologic event of the year, spring breakup; these values are therefore conservative with respect to total annual yield.

A few major events produce most of the annual sediment yield at both RCEW and CPCRW. While snow constitutes half or more of the annual precipitation in both watersheds, rainfall events produce the majority of the basin sediment yield from these watersheds (except for the

Table1. Ice-free season suspended sediment yield from Caribou-Poker Creeks Research Watershed (tonnes).

Year	Ice-free Season	Basin C-2, 5.2 km^2	Ice-free Season	Basin C-3, 4.5 km^2
1978	June 22-Oct. 1 (102 days)	0.0502	June 22-Oct. 1 (102 days)	0.0481
1980	June 17-Sept. 23 (99 days)	0.2996	June 17-Sept. 9 (85 days)	0.2768
1981	May 20-Oct. 7 (141 days)	2.2205	June 4-Sept. 23 (112 days)	5.6044
	Seasonal Mean (tonnes)	0.8234		1.9764
	Unit Area Mean (tonnes/ha)	0.0016		0.0043

high-elevation Reynolds Mountain sub-basin in RCEW). Vegetation has a significant impact on sediment production. Sediment yield is low in drought years and much greater in high-flow years.

Biodiversity: Protection and maintenance of biological diversity is essential to sustaining the integrity of forest and rangeland ecosystems, and for conservation and sustainable production of commodity and non-commodity values. Loss of biological diversity in the United States is continuing despite increased public attention and management efforts (Keystone Center 1991). Strategies for conservation and maintenance of biological diversity, particularly in the face of global anthropogenic pollution and climate warming, must be based on comprehensive research and documentation of ecosystem change over time on sensitive forest and rangelands (Society of American Foresters 1991).

In one step toward assessing plant community composition and diversity, eight exclosures, ranging from 0.8 to 14 ha, were installed in 1971 in representative plant communities of RCEW (Table 2). During 1971 to 1981 a forage production, botanical composition, and ground cover study on grazed and nongrazed (exclosures) sites was conducted (Hanson et al. 1994). Grazing intensities were monitored, annual herbage yields by species were determined, and basal and canopy cover were obtained from transects. The sites were remeasured in 1993, and data used to calculate current species richness, diversity and evenness. Future analyses will evaluate the long-term effects of climate and grazing on plant species richness, diversity, evenness, and species distribution and pattern.

In central Alaska a network of 24 vegetation monitoring and research sites was established in BCEF, in successional forest stands following alluvial floodplain deposition and following wildfire in uplands, to monitor ecosystem development and change. On the floodplain five stages of succession are each replicated three times. In the uplands, three stages following wildfire in white spruce (1780, 1910, and 1983 fires) are each replicated three times. Measurements include detailed mapping of trees on 50 m x 60 m plots, recording understory and forest floor vegetation changes on 1- and 4-m^2 plots and measuring annual productivity, litter fall, and seed fall. Environmental measurements at the sites include air and soil temperatures, precipitation, depth of seasonal thaw, and photosynthetically active radiation (PAR). Four permanent 25-ha (500 m x 500 m) long-term forest reserve (LTFR) sites were subsequently established in CPCRW in 1987. LTFR sites provide permanent references for monitoring vegetation development in four of the major vegetation/landscape settings (Table 3) found in CPCRW and the Yukon-Tanana Uplands of central Alaska: cold, north-aspect, permafrost-underlain open coniferous woodland; cold, permafrost-underlain valleys with riparian tall shrub and open coniferous woodlands; warmer south-aspect, permafrost-free deciduous (at least at present) forest; and high-elevation coniferous forest and tall shrub communities at or near tree line. Detailed mapping of trees, saplings, and seedlings has been accomplished on 1/4-ha (50 m x 50 m) plots located at each corner of LTFR plots. While the initial work did not include forest understory or forest floor species, these permanent, documented LTFR sites complement the vegetation sites in BCEF in providing opportunities for more detailed vegetation biodiversity research in the subarctic boreal forest.

SUMMARY

Sustained production of watershed values entails maintenance of the physical, biological, and social landscape characteristics which support those values. Research into physical and biological processes and sustainable resource management techniques is facilitated by dedicated landscape units which are representative of the larger ecoregion and available for repeated, long-term measurement and analysis. Streamflow, nutrient, and sediment yield regimes reflect geologic, geomorphic, climatic, soil, plant cover, stream channel, and land use influences within a watershed, and may vary markedly in response to differences in any or all these factors. Similarly, biological diversity of forest and range ecosystems may be studied in the larger context of long-term research watershed programs; the value of baseline information acquired at biodiversity plots is enhanced by sustained watershed research.

Watershed research offers: a landscape-scale ("real world") context for plot studies; an interdisciplinary base of research and monitoring over years to decades; long-term annotated, reviewed data bases; opportunities for validation and application of simulation models; complementary biological and physical process research; and a sustained institutional commitment which may be difficult to achieve for isolated plot studies. The RCEW and CPCRW/BCEF sites, like most successful field stations, are proving valuable for research and monitoring beyond the original intentions of the founders. They constitute de facto landscape-based "geosphere-biosphere observatories" with significant current and potential value to interdisciplinary watershed ecosystems research.

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Table 2. Site descriptions of exclosure and study sites at Reynolds Creek Experimental Watershed (from Slaughter et al. in press).

Location name	Soils, Geology, Slope (%)	Plant Community Type	Range site	Elev. m	Aspect	Mean annual ppt (mm)	Current vegetation
Summit	Hardtrigger gravelly sandy loam (fine loamy mixed mesic xerollic haplargid); granitic;(9.0%)	Wyoming big sagebrush	Sandy loam, 20-30 cm ppt., Wyoming big sagebrush (*Artemisia tridentata*, subsp. *wyomingensis*)/Indian ricegrass (*Oryzopsis hymenoides*)	1304	W	244	Wyoming big sagebrush; bottle brush squirrel tail (*Elymus elymoides*) Indian ricegrass
Flats	Tindahay (sandy mixed mesic xeric torriorthent); alluvial;(5%)	Salt desert shrub	Sandy, 18-25 cm ppt, Shadscale saltbush(Atriplex conferifolia) /Indian ricegrass/ bottlebrush squirreltail	1184	N	230	Shadscale saltbush/ bottle brush squirreltail
Quonset	Larimer (fine, loamy, over sandy-skeleton, mixed mesic, ustollic haplargids); basalt;(6.0%)	Wyoming big sagebrush	Loamy 25-33 cm ppt, Wyoming big sagebrush/ bluebunch wheatgrass (*Pseudoroegneria spicata*)	1193	NE	271	Wyoming big sagebrush, rubber rabbitbrush, Sandberg bluegrass (*Poa sandbergii*)
Nancy Gulch	Gariper (fine, montmorillonitic mesic, xerollic paleargid); basalt;(8.0%)	Wyoming big sagebrush	Loamy 25-33 cm ppt, Wyoming big sagebrush/ bluebunch wheatgrass	1414	NE	283	Wyoming big sagebrush, Sandberg bluegrass, bluebunch wheatgrass
Whiskey Hill	Quicksilver bouldery, coarse sandy loam (loamy mixed frigid lithic xerocrept); granite (15%)	Curleaf Mountain Mahogany	Mahogany savanna, 40-56 cm ppt, Curleaf mountain mahogany (*Cercocarpus ledifolius*)/ snowberry (*Symphoricarpos oreophilis*)/Idaho fescue (*Festuca idahoensis*)	1695	E	701	Wyoming big sagebrush, Sandberg bluegrass, bluebunch wheatgrass
Lower Sheep	Vitale (loamy skeletal mixed frigid typic argixeroll); basalt;(16%)	Low sagebrush	Shallow claypan 30-40 cm ppt, low sagebrush (*Artemisia arbuscula*)/Idaho fescue	1649	NW	339	Low sagebrush, Sandberg bluegrass, Idaho fescue
Upper Sheep	Parkay gravelly silt loam, stony (loamy skeletal mixedargic pachic cryoboroll); basalt; (33%)	Mountain big sagebrush	Loamy 16"+ Mountain big sagebrush/Idaho fescue	1859	NE	508	Mountain big sagebrush, (*Artemisia tridentata*, subsp. veseyana) Idaho fescue
Reynold's Mountain	Bullrey (fine loamy mixed pachic cryoboroll); Rhyolite;(5%)	Mountain big sagebrush	Loamy 16"+ Mountain big sagebrush/Idaho fescue	2097	SW	749	Mountain big sagebrush, Mountain snowberry, Idaho fescue,

Table 3. Long-term forest reserve (LTFR) sites in the Caribou-Poker Creeks Research Watershed (from Slaughter et al. in press).

Site	Vegetation	Soils	Aspect
LTFR A, south of Caribou Creek.	The overstory is an open coniferous woodland dominated by small, slow-growing black spruce. The mineral soil is overlain by a continuous thick organic cover of Sphagnum and feather mosses as much as 30+ cm thick.	Ester silt loams (histic lithic cryaquepts), The site is completely underlain by permafrost at shallow depth	N
LTFR B, contiguous to site A sharing a common east-west boundary, a 500 m reach of the east-flowing Caribou Creek	A stream valley with typical vegetation assemblage of open coniferous woodland and riparian deciduous (tall shrub) vegetation.	Bradway silt loam (pergelic cryaquept) overlying permafrost at a shallow depth.	N
LTFR C, north side of Caribou Creek.	A closed deciduous forest of aspen and birch with major alder tall shrub components in the understory, mid-succession stage following wildfire, with occasional white and black spruce seedlings and saplings present.	Olnes and Gilmore Silt loams (typic cryorthent and typic cryochrepts).	S
LTFR D, an upper-elevation setting encompassing both south and north sides of the east-west trending ridgeline west of Caribou Peak.	Open and closed coniferous woodland grades into tall shrub communities at the ridgeline.	very shallow Fairplay silt loam (aquic cryothent) over Birch Creek Schist; permafrost may be locally absent.	N, S

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TRASH RODEO: CASE STUDY OF A WATERSHED EFFORT

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ABSTRACT

In order to clean solid waste from a Wild and Scenic River, educate the public about water quality issues, and research methods of trash removal, we have conducted the White Salmon River Whitewater Trash Rodeo. Over the past 3 years, the event has succeeded in involving the local community in removing over 40 tons of garbage from a deep river canyon. The project is just one accomplishment of the White Salmon River Watershed Management Committee (WMC). This group addresses natural resource concerns throughout the White Salmon basin in south central Washington State. The WMC's Trash Rodeo event combines river restoration with community involvement, education, and research, and is a model for other river groups conducting clean-up efforts.

Key words: River clean-up, White Salmon River, partnerships, water quality, whitewater kayaking, watershed management.

INTRODUCTION

Over the past 3 years, more than 20 entities have collaborated to remove 40 tons of garbage from the banks of the White Salmon River in south central Washington State. During this annual Trash Rodeo clean-up event, innovative methods of deep river canyon trash removal have been tested with success. In addition, participation of community volunteers and extensive media coverage has raised awareness of local water quality issues. Multi-entity partnerships and subsequent on-ground efforts are changing the way in which our natural resources are conserved. This paper outlines how this project evolved and the important accomplishments that are the goal of any restoration effort.

WATERSHED PLANNING

The White Salmon River Watershed comprises 391 square miles of extremely diverse land that supports a variety of important biological, cultural, and economic elements. The watershed has been impacted by wide-spread residential, commercial, silvicultural, agricultural, and recreational impacts. Several years ago, this led to a concern over the sustainability of water quality and other resources that are essential to the health of the watershed. To complicate matters, various entities were working toward resource management from different directions. Consequently, conflict between interest groups was not uncommon.

In 1992, the Underwood Conservation District took action through the development of a Watershed Management Committee (WMC) composed of the different land-use interest groups in the watershed. Members include representatives of private industry, timber companies, orchardists, environmental groups, farmers, ranchers, recreationists, concerned citizens, government agencies, and private landowners. This group, often referred to as "stakeholders," acts as an oversight committee making decisions concerning the direction of natural resource conservation. This holistic approach has many advantages, most importantly the creation of self-governed land stewards working toward long-term resource protection and sustainability.

Through a collaborative effort, the WMC produced an enhancement plan for the watershed, outlining a comprehensive strategy for improving basin water quality. The group agreed to tackle resource conservation by four means: conducting on-ground restoration projects; offering cost-share and technical assistance to landowners; implementing citizen involvement and environmental education efforts; and recommending changes to current land-use regulations.

CLEANING UP

One of the water quality threats identified by the WMC was the presence of solid waste dumps along a federally designated Wild and Scenic section of the White Salmon River. For years, the local community had been

dumping garbage into the river gorge, unaware of the detrimental effects. The trash ranged from cans and bottles to appliances and car bodies. In addition, household hazardous waste items were creating an immediate threat to river water quality.

Removal of the riverside trash concurred with the strategies outlined in the enhancement plan and has since become an annual event with watershed-wide support. Corporate sponsors include Pacific Power, Westinghouse Hanford Company, Bechtel Hanford Company, Enpac Corporation, Bonneville Power Administration, and Regional Disposal Company. Many local businesses donate to the effort as well. Other important cooperators are the landowners who provide access and equipment. Finally, the project would not be a success without the support of kayakers, rafters, and ground-based volunteers who remove trash during the event.

Each entity involved in the Trash Rodeo has something to gain. The local kayaker or rafter will have a cleaner and safer float trip, the businesses will receive media exposure, the landowners will see increased property values, and fish and wildlife habitat will improve. Everyone will benefit from increased water quality and aesthetics in the basin.

RESEARCH OF TRASH REMOVAL METHODS

Unfortunately, river canyons are a common place for trash disposal. The difficulty of accessing these areas often requires innovative trash removal techniques. In the case of the White Salmon River, a steep 1/4-mile access trail, 50-foot rock faces, dense forest, and private property created obstacles. We were therefore left with two options: helicopter extraction and river-based removal.

Helicopter extraction was accomplished through the support of Bonneville Power Administration. Ten tons of trash, including large items such as car bodies and appliances, were removed in this manner. Fortunately, the helicopter time was donated, as it can be prohibitively expensive otherwise. While we were lucky to get the largest items airlifted out, we had to explore other options for the bulk of the trash.

Years ago, the river's power was used for transporting timber to sawmills downstream. We wondered why it couldn't now be used to transport trash. Our search for downriver transport containers led to support from such unlikely partners as US Department of Energy, Westinghouse Hanford Corporation, and Enpac Corporation of Ohio. We obtained from Enpac Corporation 17 high impact, roto-molded polyethylene containers with 95-gallon capacity. Designed for the containment and incineration of leaking hazardous waste drums, they make excellent watertight downriver transport vessels. With large, screw-tight lids, they are big enough to carry a significant amount of garbage and durable enough to manage the class IV-V whitewater of the White Salmon River.

During the event, empty barrels are lowered by rope and carried by hand to the dumpsite. Volunteers fill them with trash and toss them into the river. Expert kayakers "corral" the barrels downstream, keeping them from getting hung up on rocks or in eddies. Once the barrels reach an access point they are removed from the river and the trash is transported to a proper facility. The barrels are then returned to the dumpsite for reuse.

We have experimented with other methods as well. One technique involves tethering the floating barrels to a rope, stopping them at a designated spot, and hauling them out of the gorge by cable. Another method consists of pulling the barrels up the rock face with rope. However, the most efficient method is to simply let the barrels float freely with kayakers at the helm.

We feel that the possibilities are endless and that many of our nation's rivers could benefit from this technique. Of course, other streams would require their own specific approach depending on whitewater difficulty and access. We have made our barrels and technical assistance available to other groups who are interested. Moreover, additional barrels could easily be acquired.

CITIZEN INVOLVEMENT AND EDUCATION

By organizing a community event, we provide an opportunity for those who benefit from a clean river to assist in preserving their common resource. Additionally, we educate people about environmental issues.

The Trash Rodeo is successful in attracting volunteers because it is much more than just picking up garbage. It is an interesting and entertaining event. Following the event there is a celebration with live music and food. We also have a raffle prize drawing for volunteers. Many local businesses contribute prizes, ranging from free pizza to $400 donations.

The event also serves as a good venue for disseminating information about water quality issues. We feel strongly that raising awareness of environmental topics puts responsible land stewardship into the hands of the people. Informational speeches have been an effective way of educating participants on local issues and conservation actions. County commissioners and representatives of sponsoring organizations have spoken at the Trash Rodeo events. Other outreach programs involve the news media, door-to-door visits, mailings, and presentations at conferences and workshops.

CONCLUSIONS

Cleaning up a local waterway is just one example of the many ways the public can significantly contribute to the quality of our shared environment. Protecting our common resources relies heavily on the participation of the community, whether it be planting trees, recycling, picking up trash, or watershed management planning. With increasing pressures exerted on our natural resources and booming populations and industries encroaching on local watersheds, we have become less and less connected with the land. Through educating people about what they can do to help, providing opportunities for involvement, and making conservation work a fun and rewarding experience, we re-establish the link between community and environment.

DEVELOPMENT OF A STREAM TEMPERATURE STANDARD FOR OREGON

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ABSTRACT

Temperature concerns in many of Oregon's streams and rivers normally occur during summertime periods when solar energy loadings are high and streamflows are low. Excessively high temperatures at this time of year can often be detrimental to many fish species and aquatic organisms. In 1992, Oregon initiated a review of its stream temperature standard, a standard that had been originally formulated in 1967. A subcommittee was formulated to assess the adequacy of Oregon's water temperature standard and, if needed, propose alternative standards that would protect beneficial uses. In 1994, a new water temperature standard was adopted by the state; that standard and an overview of the process by which it was attained are presented in this paper.

Key Words: water quality, stream temperature, riparian management, Oregon

INTRODUCTION

A wide range of riparian conditions and water quality characteristics affect the quality of instream environments for aquatic life. Of these, stream temperatures have a prominent role because of their influence on a wide range of physical, chemical, and biological processes (Beschta et al. 1987, Department of Environmental Quality 1995). For example, water temperatures not only regulate the biological activity of organisms (higher temperatures result in increased metabolic rates), but the capability of water to hold oxygen decreases with higher temperatures. Thus, stream temperatures have the capability of directly, via their regulation of metabolism, or indirectly, via their influence on other processes, to influence the growth and survival of aquatic organisms. The purpose of this paper is to overview the process and some of the technical issues associated with the temperature standard that was recently promulgated for Oregon waters.

In the upper Columbia River Basin, decreasing salmonid populations over recent decades have resulted in an urgent need for improving the management of watersheds, fisheries habitat, and water quality. Wild salmon, which once numbered in excess of 10 million returning adults for the Columbia River Basin alone, have declined to less than one-tenth that number (National Research Council 1996). A wide range of natural factors (ocean conditions, climatic variations) and human factors (fishing, dams, hatcheries, urbanization, streamside roads, and others) have undoubtedly had a profound influence on salmon populations.

Once adult salmonids enter freshwater streams and rivers they are critically dependent upon the quality of the water and instream habitats—particularly for spawning and rearing. Throughout much of the upper Columbia River Basin, a stream's thermal regime is often a critical feature of habitat quality, especially during summertime conditions. Furthermore, human influences (e.g., the withdrawal of water for irrigation, the logging of riparian forests, the removal of streamside shrubs and herbaceous vegetation by grazing) can have major effects on stream temperatures, particularly during summertime periods.

WATER QUALITY STANDARDS AND BENEFICIAL USES

Under the Federal Clean Water Act, states are obligated (1) to identify beneficial uses for state waters and (2) to adopt water quality standards that protect those beneficial uses. In Oregon, beneficial uses include: domestic water supply, industrial water supply, irrigation, livestock watering, fish passage, salmonid spawning and rearing, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation, aesthetic quality, hydropower, and commercial navigation and transportation.

A water quality standard generally consists of narrative or numeric components that describe specific criteria that will protect beneficial uses. Narrative statements typically define limits, perhaps indicating that certain waters will be maintained free of some condition. Numeric standards specify a concentration or some other

value (e.g., temperature) to be maintained above or below specified levels. While certain water quality standards may be applied uniformly to all waters of the state, in other instances they may vary for individual basins or geographic regions.

PREVIOUS TEMPERATURE STANDARD

Oregon's first stream temperature standard, adopted in 1967, identified a maximum temperature level above which no additional change was allowed. However, if background stream temperatures were below the specified maximum, some increase was acceptable. For most basins east of the Cascades, the 1967 temperature standard typically indicated:

No increase when stream temperatures were 68°F (20°C) or greater; or no more than a 0.5°F increase when water temperatures were between 66°F and 67.5°F; or no more than a 2°F increase when natural background temperatures were 66°F or less.

For basins in the western part of the state, a maximum temperature of 64°F (17.8°C) was commonly specified as the maximum allowable. Again, increases of 0.5°F or 2°F were acceptable depending upon the extent to which background temperatures were lower than the specified maximum.

PROCESS FOR DEVELOPING A "NEW" STREAM TEMPERATURE STANDARD

In 1992, a water quality subcommittee was formed (co-chaired by Debra Sturdevant, Oregon Department of Environmental Quality, and Dr. Stan Gregory, Oregon State University). The subcommittee was comprised of 11 members representing several state agencies, researchers, tribal interests, and industry. The purpose of the subcommittee was (1) to review the existing water temperature standard and (2) to assess the need (if any) for developing a new water temperature standard (Department of Environmental Quality, 1995).

One of the first tasks of the subcommittee was to assess the relevance and applicability of the 1967 water temperature standard. It was soon apparent that there was a lack of information and documentation indicating how the original water temperature standard for Oregon was developed. Little information was available that explained either the procedure by which the original standard was formulated or how the numeric criteria were ultimately chosen. In addition, the concept of a "natural background" temperature was unclear as to whether it represented an instantaneous maximum temperature, an average stream temperature over the course of a day, mean monthly maximum temperature, or some other formulation. The wording of the 1967 standard seemed to indicate that it was directed primarily at point-source types of water temperature situations; the usefulness and applicability of the standard for non-point situations was unclear. Various attributes and concerns associated with the 1967 temperature standard were considered by the temperature subcommittee and have been summarized in an issues paper (Department of Environmental Quality, 1995).

Since adoption of the 1967 temperature standard by the state of Oregon, much has been learned regarding the role of temperature in aquatic systems and factors affecting the thermal regimes of streams and rivers. While a large number of beneficial uses are potentially affected by water temperatures, some of those most sensitive to changes in stream temperature are instream organisms, including resident and anadromous fish. Thus, the subcommittee focused much of their effort on evaluating the thermal needs of cold- and cool-water fish (salmonids) and associated aquatic organisms. Focusing on indicator species with documented sensitivity to stream temperatures was based on an assumption that if a temperature standard was protective of those species, other species and other beneficial uses with less rigid thermal requirements would also be protected.

One of the primary responsibilities of the temperature subcommittee was to accumulate, organize, interpret, and discuss information regarding such topics as sub-lethal effects of temperature on salmon and trout (physiological consequences, acclimatization and adoption, food availability, competition, cumulative degree days), temperature requirements by life history stage for salmon and trout (Chinook, coho, bull trout, sockeye), aquatic amphibians, watershed scale issues (cumulative effects, the role of refugia), environmental variability of temperature (spatial, temporal), temperature alteration and fish use (point and non-point effects), and interactions with other water quality constituents (dissolved oxygen) (see Chapter 2, Appendix D, Department of Environmental Quality 1995). Several conclusions related to these topics were subsequently developed:

* Nearly all native Oregon fish species are classified as cold- or cool-water species.

* For Pacific Northwest salmon species, the incidence of disease increases significantly when temperatures exceed 60-62°F (15.5-16.7°C).

* Bull trout are typically found in streams with temperatures less than 54°F (12°C) for most life stages.

* In order to maintain sustainable fish populations, a temperature standard must be based on temperatures that allow individuals to remain healthy and successfully reproduce.

* Not only absolute temperatures, but the overall temperature regime (the temporal pattern of stream temperatures throughout the year) is important for sustaining fish and other aquatic organisms.

* Oregon is toward the southern (warm) end of the geographic range in which many cold-water fish species occur. Thus, there is often little opportunity to increase summertime stream temperatures and still maintain viable cold-water communities and fish populations.

* Insufficient information is available to distinguish different temperature requirements, if any, for various stocks of cold-water fishes.

* The direct and indirect effects of stream warming on aquatic organisms occur along a continuum. During summertime conditions, the severity of an effect generally becomes greater with increasing temperature. Any specific temperature identified in a water quality standard is a point along that continuum.

* Stream temperatures vary naturally in the environment through time (e.g., daily, seasonally, following natural disturbances) and with long-term climatic changes. Stream temperatures also exhibit natural geographic variability (e.g., headwaters vs. lower reaches).

* Summertime stream temperatures recorded over the past several decades are generally warmer than is optimal for cold-water fish species. Land use activities, point sources, and natural factors have contributed to this condition.

A general water temperature concern with many of Oregon's streams is the occurrence of high temperatures that occur during summer months and the impacts these elevated temperatures might have on a wide range of aquatic organisms. Maximum temperatures typically occur in Oregon streams during July, August, or September when incoming solar radiation levels are high and streamflows are low. Summertime environmental conditions are particularly important to salmonid life history stages, which include upstream migration of adults, spawning, egg development, and juvenile rearing (See Figure 1).

Based on the above considerations and other information, alternative temperature standards were considered by the temperature subcommittee (Department of Environmental Quality 1995). Ultimately four different formulations of a water temperature standard, each designed to protect the beneficial uses of Oregon waters, were developed by the subcommittee and submitted to a Policy Advisory Committee.

In 1994, after extensive consideration of the temperature standard alternatives the Policy Advisory Committee recommended acceptance of a 64°F (17.8°C) numeric criterion for most waters in Oregon. The 64°F (17.8°C) temperature was to be calculated as a moving average of

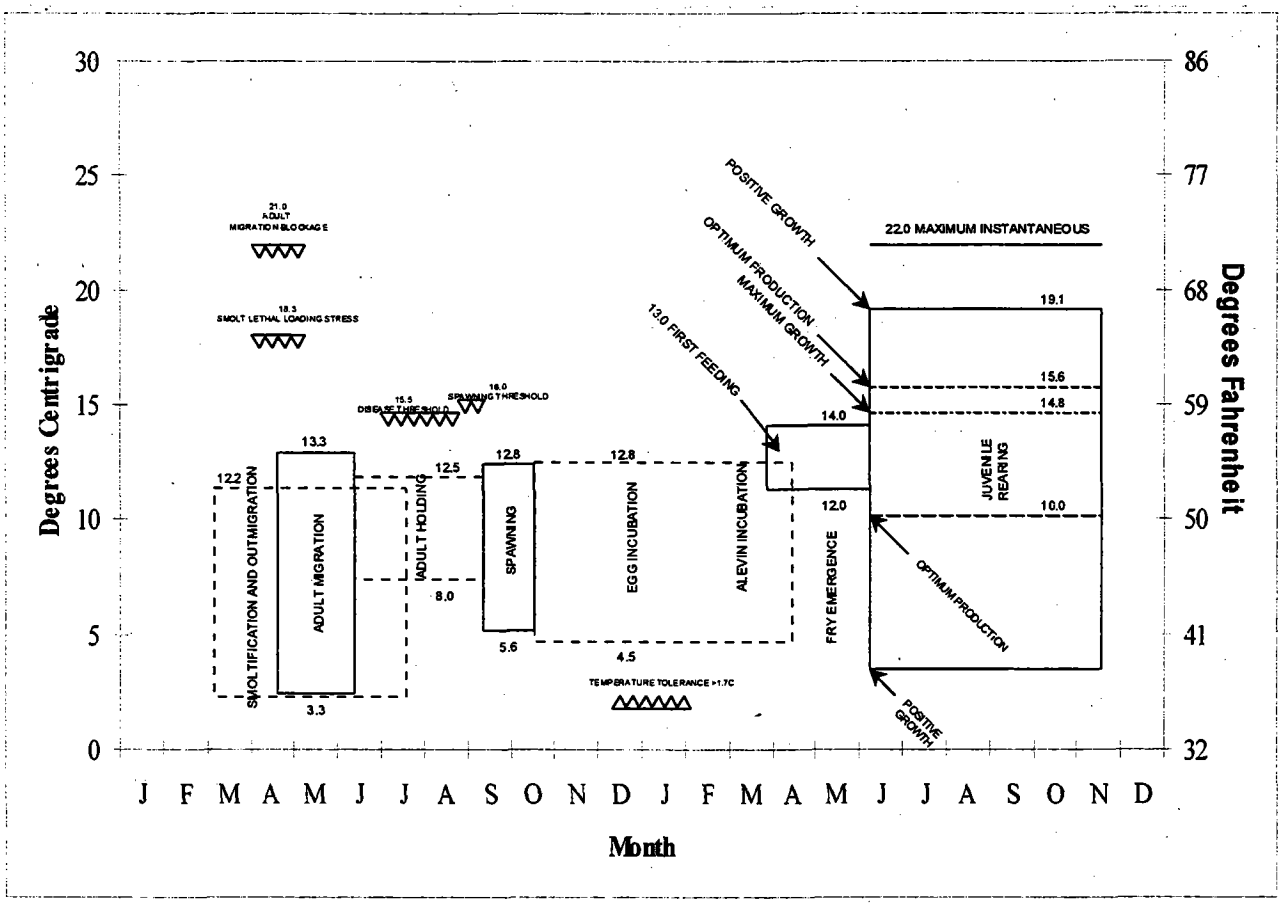

Figure 1. Spring Chinook temperature requirements by life stage (from Department of Environmental Quality 1995).

the daily maximum temperature over a 7-day period. The primary beneficial uses to be protected by this standard were instream fisheries (both anadromous and resident) and associated aquatic organisms. For bull trout waters, a 50°F (10°C) temperature standard was adopted by the state.

Included with the numeric criterion was a provision for the development of a basin temperature management plan to address human effects when stream temperatures exceeded 64°F (17.8°C). Furthermore, during summers of exceptionally low flows or seasonally high air temperatures (i.e., summers during which the 7-day streamflow was below a 10-year recurrence interval event and/or during which the 7-day maximum air temperature exceeded the 90th percentile), the stream temperature standard was to be waived.

UNRESOLVED ISSUES

Although a specific water temperature standard for Oregon's waters was ultimately developed by the temperature subcommittee and endorsed by the Policy Advisory Committee, several uncertainties regarding scientific knowledge surfaced during discussions and development of the standard (See Table 1). For example, what were the natural thermal regimes of individual streams across the state prior to settlement by Euro-Americans? To what extent have land use activities since Euro-American settlement affected these thermal regimes? While reach-scale stream temperature models exist which could help answer some of these questions, little research has been conducted that considers the cumulative effects of various geographic conditions, stream characteristics, flow levels, and the effects of land use activities at multiple locations along a stream system.

Table 1. Estimated uncertainties in the scientific knowledge of stream temperature and its effect on aquatic organisms (from Department of Environmental Quality 1995).

TECHNICAL COMPONENT	UNCERTAINTY CHARACTERISTICS	LEVEL OF UNCERTAINTY		
		HIGH	MEDIUM	LOW
Physiological Responses	Application of research from lab to field			X
Salmonid Requirements	Mix of field and lab studies, Assemblage of species, Complex environments			
Lethal Temperatures	Range of observed lethality			X
Food Availability	Complexity of food webs		X	
Competition	Complexity of communities	X		
Non-Salmonid Fish Requirements		X		
Amphibian Responses	Scarcity of studies	X		
Historic Fish Distribution			X	X
Historic Trends in Fish Population		X		
Historical Context	Information on historic stream temperatures		X	
Environmental Variability	Simply physics but complex environment; Complex nonpoint sources	X		
Environmental Variability of Climate - Global			X	
Basin Projections Based on Models		X		
Watershed Issues	Complexity of landscapes and cumulative effects	X		
Development of Alternatives	Social interaction with technical information base	X		
Projected Human Change			X	
Inspirational Models	Social interaction with technical, application of management	X		
Cumulative Effects of Implementation		X		

The temperature subcommittee did not have the resources to specifically assess the effects of various human activities upon stream temperatures across drainage basins and geographic regions. Nevertheless, there was general agreement within the subcommittee that high summertime water temperatures associated with many Oregon streams could be lowered by improved land use practices—particularly those practices associated with riparian zones. The extent to which such changes in land use can lower summertime maximum temperatures is not known, but collectively could be quite large. Demonstrating the magnitude of possible improvement in summertime maximum temperatures that is attainable for any given stream and drainage basin represents a continuing challenge to researchers, to land owners, and to Oregonians in general as society attempts to improve instream conditions for fish, aquatic organisms, and other beneficial uses. The water temperature standard adopted in 1994 provides a quantitative goal for assessing that progress.

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INCORPORATING DRINKING WATER PROTECTION INTO THE WATERSHED APPROACH

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ABSTRACT

The 1996 Safe Drinking Water Act Amendments require states to implement Source Water Assessment Programs (SWAPs) for sources of drinking water used by public water systems (PWSs). The assessments include (1) delineation of the drinking water protection area (DWPA), i.e., the critical part of the aquifer or watershed that supplies the PWS, (2) an inventory of potential sources of contamination within the DWPA, and (3) a susceptibility analysis to determine the relative threat of these sources to drinking water quality. The information derived from the assessment can then be used by the local community to develop management strategies designed to reduce that threat. The 1996 Amendments provide Oregon with the opportunity to expand its EPA-approved drinking water protection program for groundwater, a.k.a. wellhead protection, to include PWSs that use surface water as their drinking water source. For surface water sources, EPA's 1997 Guidance requires that the entire watershed be delineated topographically, recognizing, however, that because of watershed size and/or location of the PWS intake, enhanced delineations, e.g., subwatershed areas, buffer zones, and set backs, may be used to focus management activities. Conjunctive delineations may be important where groundwater and surface water interact. Recognizing the number of state and federal programs addressing water quality issues in watersheds, it will be necessary and more efficient to integrate drinking water protection with other agencies, organizations, and programs. The Oregon Department of Environmental Quality will form a Drinking Water Protection Advisory Committee, including relevant stakeholders, that will have the responsibility of developing Oregon's program to protect drinking water sources in watersheds.

Key Words: wellhead protection, drinking water, delineation, susceptibility analysis, groundwater-surface water interaction, public water systems, watersheds

INTRODUCTION

The availability of a clean public drinking water supply is fundamental to the location and viability of communities. For obvious reasons, population centers develop in areas where drinking water is safe and abundant. Often this has been in river valleys where streams are close by and highly permeable sand and gravel aquifers are near the surface. Unfortunately, the readily available nature of these water resources, which makes them desirable as sources of drinking water, also makes them highly susceptible to contamination from the very activities that are associated with the growing population, e.g., waste disposal, industrial discharges, stormwater runoff, agricultural activities, etc.

In the 1970s federal legislation, e.g., the Clean Water Act of 1972, was enacted to address the growing problem with the nation's waters. Among these laws was the Safe Drinking Water Act (SDWA) of 1974 which was directed at ensuring that the water delivered to individuals by public water systems was safe to drink. The early focus of the SDWA was on the monitoring of drinking water for contaminants and the treatment, if necessary, of the water to remove contaminants. That focus broadened with the 1986 and 1996 Amendments to the Act which added prevention to the tools communities can use to ensure the quality of their drinking water source.

Source water protection is now considered the first "barrier" in the four-barrier strategy to provide the public with safe drinking water: source water protection, water treatment, distribution system management, and contaminant monitoring. It is well documented that source water protection is a highly cost-effective way to avoid the added expense of increased monitoring and additional water treatment.

In 1990, a volatile organic compound (VOC) was discovered during first-time routine monitoring of the

groundwater from wells serving a small community (~300 residents) in the Willamette Valley, south of Portland, Oregon. Because the contaminant exceeded the health standard, i.e., the maximum contaminant level (MCL), established by the EPA for drinking water, the residents were not permitted the use of the water for drinking or cooking and had to rely on bottled water for that purpose for nearly 2 years. During that time, property values declined markedly and there was significant discontent among residents. The total cost of the site investigation and the establishment of an aeration/granular activated carbon treatment, paid out of state funds, exceeded $500,000, equivalent to more than $1,650 per resident. In addition, the operation and maintenance costs associated with the treatment process has increased monthly water bills by approximately $20. If a source water protection plan, which would have cost approximately $15 per resident, had been in place, it is probable that the contamination that impacted this community would never have occurred.

The 1986 Amendments to the SDWA required states to develop Wellhead Protection Programs, designed to provide protection for groundwater-based public water systems. The 1996 Amendments extend that strategy to watersheds, i.e., focusing preventative actions in areas where surface water is the source of drinking water for a public water supply. The 1996 Amendments also make the important connection that is a foundation of the hydrologic cycle: groundwater and surface water are part of the same system.

The purpose of this paper is to describe Oregon's existing drinking water protection program and how the new Amendments of the SDWA will be used to extend that protection to surface water sources. This paper discusses Oregon Public Water Systems, Wellhead Protection, the 1996 Amendments, and integration of drinking water protection with other programs.

OREGON'S PUBLIC WATER SYSTEMS

For monitoring requirement purposes, public water systems are classified based on the level of exposure to drinking water the individuals present at the site experience. At facilities where individuals have only short-term exposure, e.g., a campground, restaurant, motel, the monitoring focuses on those chemicals that may cause an acute response, i.e., a response after only one exposure. Typical monitoring at these sites may consist primarily of periodic monitoring for coliform bacteria and nitrate/nitrite. At sites where the individuals drink the water over a longer period, e.g., schools, work places, and residences, monitoring focuses not only on contaminants that result in an acute response, but also those that produce a chronic response. As a result, monitoring is much more extensive and includes inorganic and organic contaminants that have been identified by the EPA and the state.

In Oregon, a public water system is defined as a facility providing piped water for human consumption to more than 3 service connections, or supplying water to a public or commercial establishment which operates a total of at least 60 days per year and which is used by 10 or more individuals per day or that is licensed by the Oregon Health Division (OAR 333-061-0020 (94)). Oregon has approximately 3,550 public water systems which are grouped as follows:

Community1 Systems: Where people live. Approximately 880 systems serving ~2,300,000 people.

Nontransient Noncommunity1 Systems: Where people work or go to school.

Approximately 330 systems serving ~70,000 people.

Transient Noncommunity1 Systems: Where people visit, e.g., campgrounds, motels, and restaurants. Approximately 1,475 systems.

State-Regulated Systems2 : Small residential areas and businesses. Approximately 860 systems serving ~16,000 people.

1. Federal (EPA) classification

2. Classification adopted by Oregon to extend federal classification (minimum of 15 connections or 25 people served) to smaller systems (minimum of 4 connections or 10 people served).

Most of Oregon's public water systems are small, e.g., over 600 of Oregon's community water systems serve less than 500 people. Approximately 3,200 of Oregon's public systems derive the bulk of their drinking water from groundwater, while only 350 systems depend primarily on surface water (OHD 1995). Although there are fewer surface water systems, these systems serve the majority of the population because they include the major population centers in the state, e.g., Portland, Salem, Eugene, and Bend. Figure 1 shows the distribution of public water systems in Oregon. As illustrated, the bulk of the water systems occur west of the Cascades within the Willamette Valley.

MONITORING OF GROUNDWATER AND SURFACE WATER SYSTEMS

As indicated above, public water systems are regulated by the Safe Drinking Water Act, which stipulates monitoring for biological and chemical contaminants, defines treatment techniques as appropriate, regulates the addition of new systems or modification of existing systems, and details issues concerning dissemination of information to the public. In Oregon, the Health Division has primacy, or primary enforcement responsibility, of the Safe Drinking Water Act.

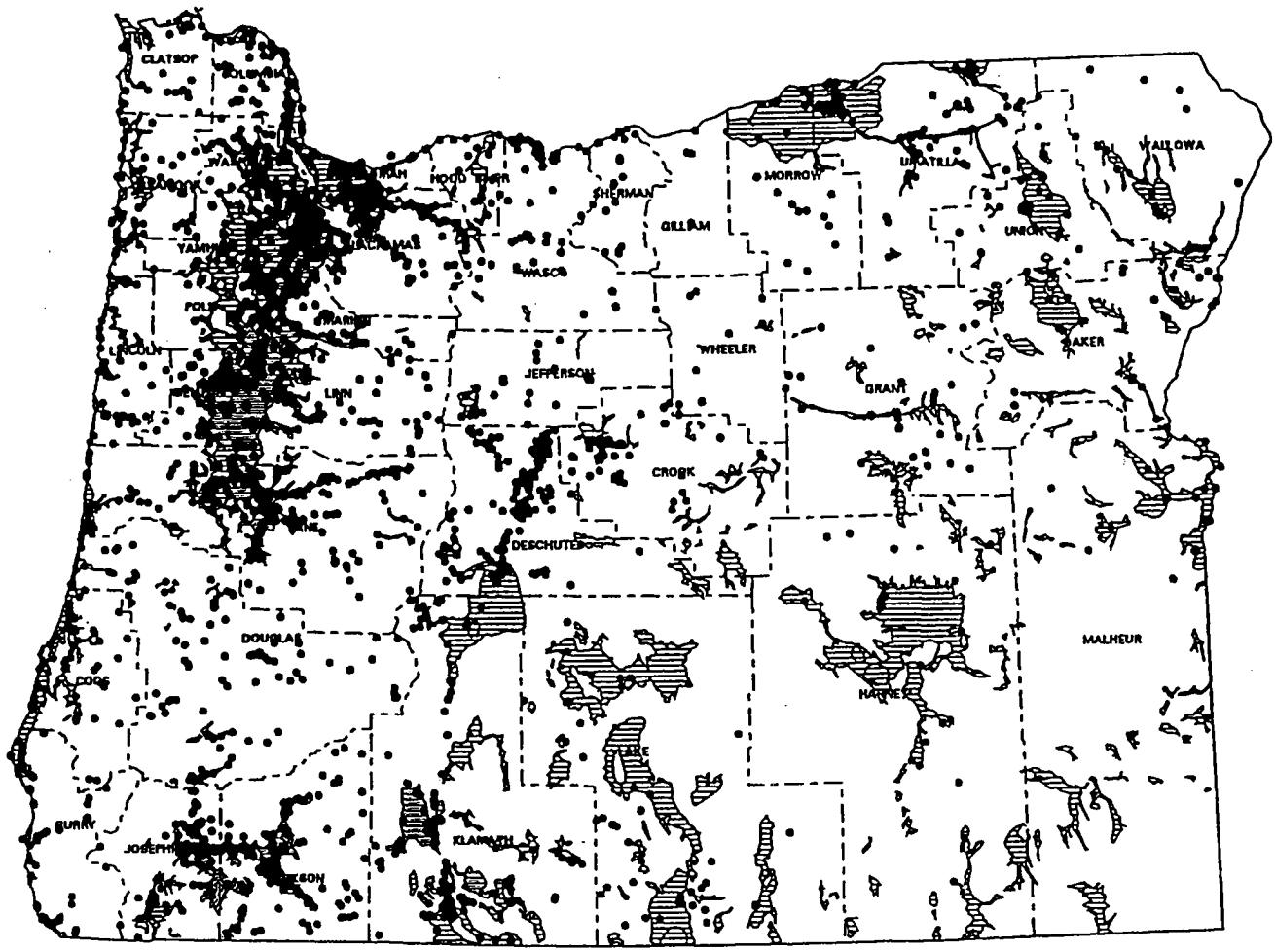

Figure 1. Map of Oregon showing public water systems (filled circle) and areas where alluvial deposits occur (horizontal ruled).

Monitoring of drinking water supplied by public water systems was significantly enhanced by the 1986 Amendments to the SDWA, adding 83 constituents to the 23 originally stipulated by the act, including a host of organic chemicals, e.g., solvents and pesticides. Since then, there have been approximately 380 detections of nonbiological constituents in public water supply sources. Of these detections, approximately 50% are organic chemicals, e.g., solvents, fuels, and pesticides; approximately 45% are nitrate concentrations in access of 5 mg/L; and approximately 5% are other inorganic, e.g., As, Cr, Ni, Cd.

Confirmed detections of nonbiological contaminants at the surface water intake of a public water system have been rare. One reason for this is that unlike groundwater, where water and contaminants move slowly (<<1 meter/day), surface water moves through the system more rapidly. Given that the frequency of monitoring for organic contaminants in surface water systems has never been more frequent than quarterly, the probability of detecting an isolated release is rather small. It is also relevant to point out that the analytical techniques used for drinking water testing (OAR 333-061-0036) do not have the sensitivity that research level instrumentation does. Trace quantities of metals and pesticides have been found in the water, suspended load, and bed load of several streams in the state (Harrison et al. 1995, Tetra Tech 1995).

The principle contaminant group of concern for surface water sources is microorganisms, particularly those associated with waterborne disease: (1) bacteria, including Legionella, Salmonella, typhi, Shigella, and Vibrio cholerae, (2) viruses, including hepatitis A and Norwalk virus, and (3) protozoa, including Giardia and Cryptosporidium (USEPA 1993). Given the probability that some or all of these organisms are present in surface water, monitoring of the source water by itself is not considered an adequate safeguard for public health. The consumption of unfiltered or inadequately filtered surface water has lead to seven documented disease outbreaks in Oregon caused by either Giardia or Cryptosporidium (OHD 1995). As a result, a treatment standard is imposed on all surface water sources used as drinking water.

Although disinfection by itself may be an effective way of eliminating bacteria and viruses, protozoa are significantly more resistant to chlorination, the most widely used disinfectant.

To reduce the risk of protozoa, filtration is required for all surface water systems unless the water system can meet specific criteria to avoid it. From the perspective of source water protection, it is noteworthy that one of the criteria that must be met for a water system to avoid installing a filter plant for treatment is watershed control. In this context, watershed control not only refers to minimizing the source of the organism in the watershed, but also control of factors that might reduce the effectiveness of the disinfection process (Robbins et al. 1991). The dissolved and suspended load of the water, which clearly is inherited from processes and activities upstream in the watershed, can interfere with the reactions necessary for proper disinfection (USEPA 1993). Robbins et al. (1991) point out that the suspended load may also interfere with the treatment process for those systems that have filter plants. Accordingly, water systems that use surface water, filtered or unfiltered, must maintain turbidity at low levels in order to ensure that the removal and/or disinfection process will function properly.

GROUNDWATER UNDER THE INFLUENCE OF SURFACE WATER

The hydrologic cycle has become the standard tool, from a directional and mass balance approach (Wanielista et al. 1997), for displaying the movement of water above, on, and below the Earth's surface (Heath 1989). From the perspective of the hydrologic cycle, groundwater and surface water are clearly interconnected. Until recently, however, many of the regulations dealing with water quality failed to make that connection, often treating these two parts of the system as if they were unrelated. In the drinking water arena, this view changed significantly with the 1986 Amendments to the SDWA. Within those amendments, a new category of drinking water sources was established: groundwater under the direct influence of surface water. The concern was that wells and springs that were in proximity to a surface water source might be vulnerable to Giardia contamination through either natural or induced infiltration of surface water.

The Oregon Health Division established a protocol for determining groundwater systems under the direct influence of surface water (Figure 2). The process first evaluates whether or not a groundwater system is in hydraulic connection to surface water, i.e., water can travel from a surface water source to the well or spring, either continuously or episodically. If hydraulic connection is established, the public water system must determine whether or not there is a risk of Giardia being transported to the well or spring.

The result of this determination has significance to drinking water protection as well as concern regarding contamination by Giardia. If a groundwater source is in hydraulic connection with surface water, then any contaminant that may be present in the surface water may enter the aquifer and impact the groundwater. This could occur when and if the drawdown produced by pumping reaches the well, or seasonally, during high stream stage, when the stream discharges to the groundwater, locally reversing the gradient causing water to flow towards the well.

Figure 3 schematically illustrates the concern regarding upstream land uses. The well receives part of the water it produces by inducing infiltration from the stream. Upstream are a number of potential sources of contamination, transportation corridors, industrial discharges, runoff from residential and agricultural areas, etc.

Approximately 85 community sources met the first criteria in Figure 2 and were evaluated, either hydrogeologically or through a 6- to 12-month duration water quality assessment. Of those, 45 sources were found to be in hydraulic connection with the proximal surface water source. Figure 4 indicates that the frequency of hydraulic connection decreases with distance from the surface water source although the local hydrogeological conditions and pump rate play a significant role. Figure 5 demonstrates that hydraulic connection tends to decrease with well depth; however, factors of well construction may be important as well.

As indicated in Figure 2, for those sources found to be in hydraulic connection, further analysis is required to evaluate the potential of Giardia being transported to the well. Oregon has adopted the Consensus Method (Vasconcelos and Harris 1992), which uses microscopic particulate analysis (MPA) for rating the risk of Giardia being present in the groundwater. The method relies heavily on the presence of indicator organisms, i.e., organisms that require light and are therefore generally not indigenous to groundwater, e.g., diatoms, other algae, insects/larvae, rotifers, and plant debris. The organisms are ranked according to their significance as surface water indicators (e.g., diatoms > other algae > insects/larvae > rotifers > plant debris), and a relative risk score is determined based on their abundances (Vasconcelos and Harris 1992). The total relative risk factor is the sum of all of the scores: total scores <10 are considered low risk while total scores >20 are considered high risk.

Figure 6 illustrates the results of MPAs that have been performed on groundwater sources that are in hydraulic connection with surface water. As anticipated, high risk sources occur closer to the stream; however, it is not uncommon for sources in excess of 100 feet from the stream to be at high risk. Further, at least one groundwater source at a distance in excess of 300 feet contained enough diatoms and/or other algae derived from the stream to be

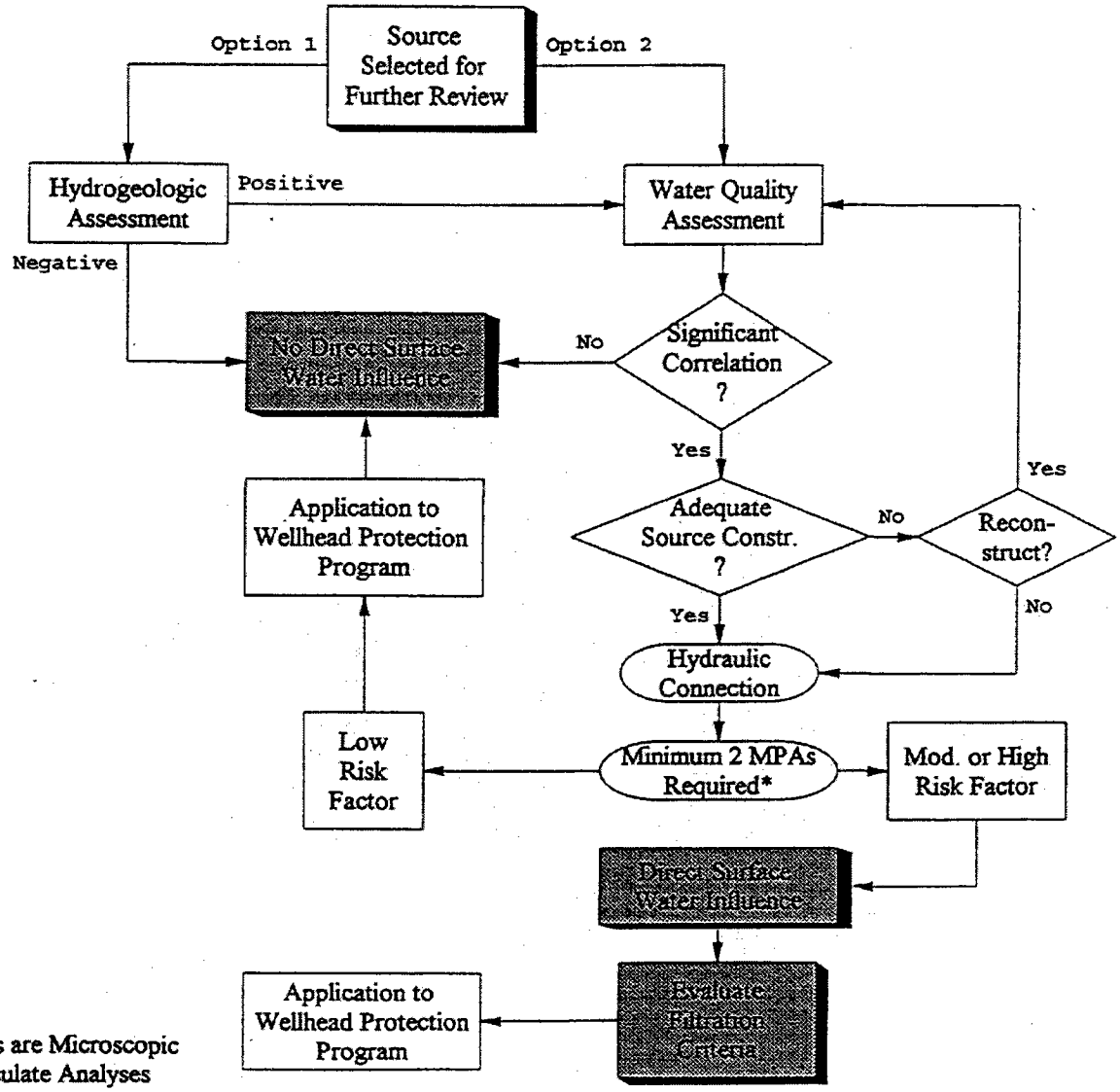

Figure 2. Protocol developed by the Oregon Health Division to determine if a groundwater source was under the direct influence of surface water, i.e., had the potential of being contaminated by Giardia-bearing surface water by natural or induced infiltration. This protocol was followed by systems that were within 150 meters of surface water and either had source-related coliform bacteria contamination or whose well construction was inadequate to prevent surface water from moving to the aquifer. The water quality assessment consists of weekly measurements of temperature and an additional parameter, e.g., conductivity, pH, etc., in both the groundwater and surface water for a period of 6 to 12 months. Source construction refers to well construction.

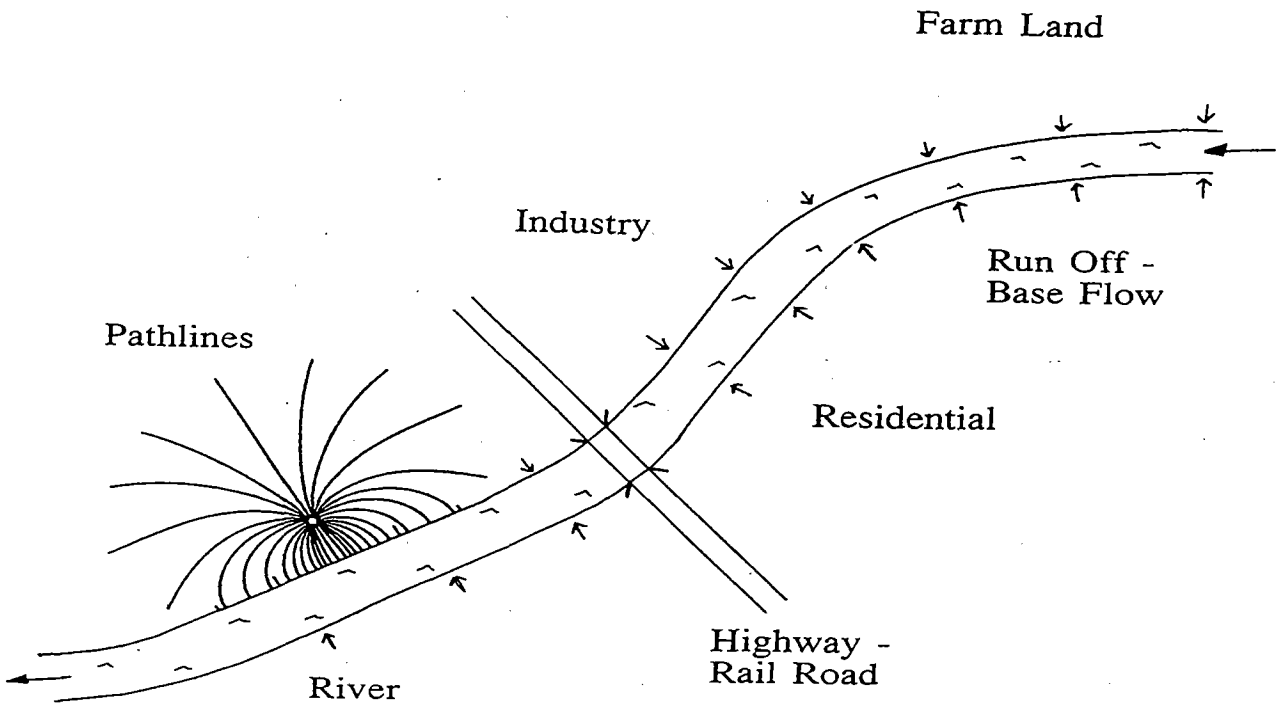

Figure 3. Sketch map of a well that is in hydraulic connection to a stream. Note that some of the simulated path lines for the well intersect the stream indicating that a portion of the water produced from the well comes from induced infiltration from the stream. Because of the hydraulic connection, the well's capture zone is susceptible to contaminants that might occur in the stream because of land use activities that occur upstream from the well site. The short arrows along the stream represent contributions to the stream from runoff, shallow interflow, or from groundwater.

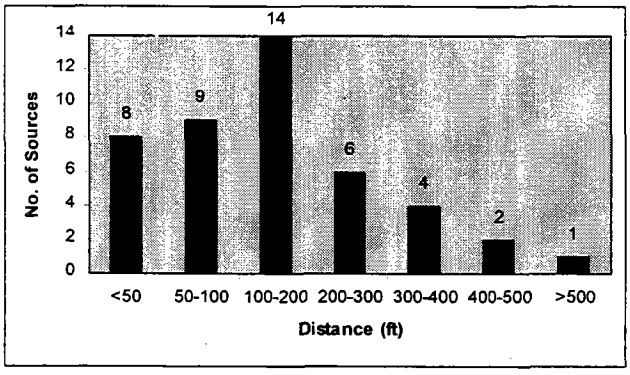

Figure 4. Number of wells in hydraulic connection with surface water versus distance. The number decreases with distance from stream. Peak at 100 to 200 feet (30 to 60 meters) reflects a higher number of wells located in that distance range rather than a higher frequency of wells in hydraulic connection.

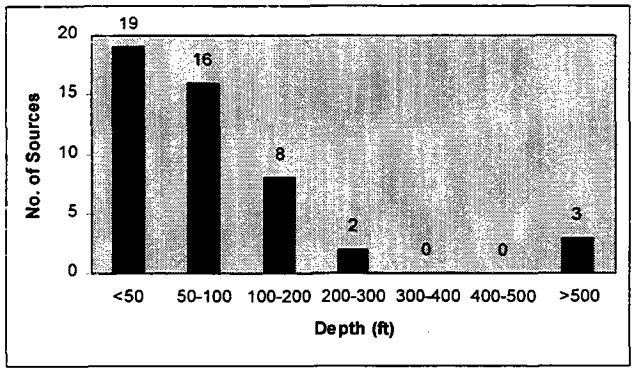

Figure 5. Number of wells in hydraulic connection with surface water versus well depth. The number decreases markedly with depth. The wells in hydraulic connection with depths exceeding 500 feet (~150 meters) are the result of inadequate well construction, i.e., pathways for surface water transport to the well casing below the casing seal exist.

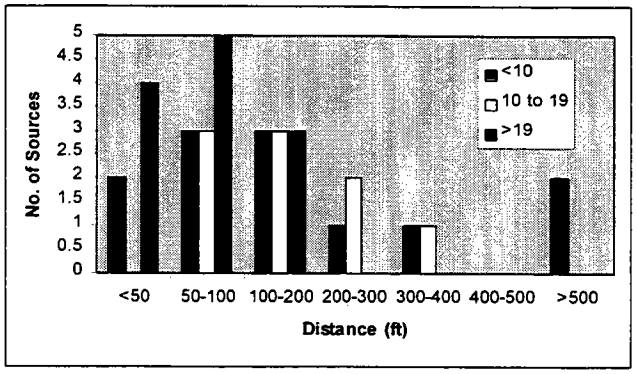

Figure 6. Relative risk scores (Vasconcelos and Harris 1992) from microscopic particulate analyses (MPAs) versus distance to a surface water source. The higher the score, the higher the relative risk of the groundwater being contaminated by Giardia (see text). Ruled bars indicate a low relative risk score (<10), open bars indicate a moderate relative risk score (10 to 19), and filled bars indicate a high relative risk score (> 19). Note that wells at a distance of 300 feet (~90 meters) may still be a moderate risk for Giardia contamination.

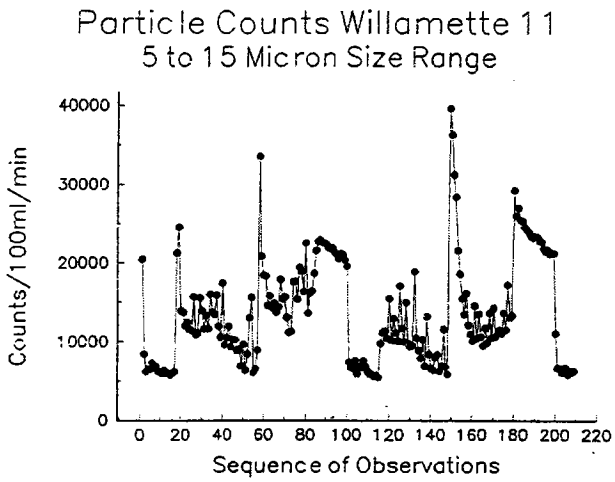

Figure 7. Particle counts in the 5 to 15 micron size range in groundwater from a well located approximately 15 meters from a stream. Each observation (filled circle) represents a 15-minute interval consisting of 5 minutes of continuous counting and 10 minutes of rest. Note the apparent cycles, particularly in the 0 to 20, 85 to 115, and 180 to 210 observation range. Prior to and during this period, there was no significant change in the particle counts of the surface water source. The cycles reflect wellfield operation. Other wells in the wellfield were cycling on and off to meet system demand. As they did so, the water table moved up and down in response. Apparently this produced the change in the particulate load detected at the wellhead. Had a single sample been taken as a "grab sample," the result would not have been representative of the water quality being produced.

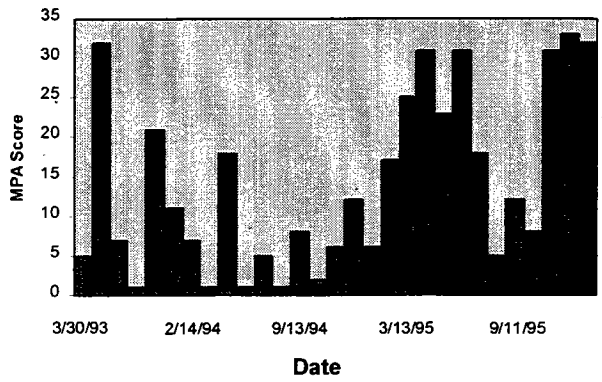

Figure 8. MPA relative risk factor scores for a single infiltration gallery along the Columbia River. Note the significant range in scores (1 to >30) indicating a variation in relative risk from low to high. Scores are apparently cyclic indicating that the variation is not random, but may be related to both pump rate and river stage. This data indicates the danger of evaluating the risk of Giardia contamination on a single sample.

considered at moderate risk from Giardia contamination.

Of interest to monitoring practices is the short- and long-term variations observed in surface water indicators. Figure 7 demonstrates the short-term (~48 hours) variation in particle counts in groundwater in the 5-15 micron size range of Giardia that appears to be related to the wellfield operation that influences the local level of the water table. Figure 8 reflects a long-term (~30 months) variation in MPA scores from an infiltration gallery. Scores range from <5 to >30. These data indicate the danger of making a decision about the existence or extent of groundwater-surface water interactions based on few data.

DRINKING WATER PROTECTION: 1986 AMENDMENTS TO THE SDWA

In the 1986 Amendments to the SDWA, the EPA mandated that the states develop an approach to prevent the contamination of groundwater sources for public water systems. Termed Wellhead Protection nationally, this was the first effort at the federal level to move from a reactive to a proactive approach to potential contamination of groundwater.

The state's Wellhead Protection Programs had to address seven elements (Witten et al. 1995):

Identify the roles and duties of the participating entities at all levels of government

Develop a method for delineating the wellhead protection area (WHPA)

Develop a method for inventorying the WHPA for potential sources of contaminants

Design options for managing those sources

Develop a process for contingency plan development to prepare for an emergency

Develop a process by which new wells will be incorporated into existing WHPAs

Ensure the opportunity for public input

The Oregon program was developed as a multiagency approach, with the Oregon DEQ as the lead agency and the OHD and ODA with strong supporting roles. During the period from 1992 through 1996, the DEQ convened two Citizen Advisory Committees to design the program. The final program, approved by the EPA in September of 1996. is a voluntary program that is based on significant local input. Reflecting the program components listed above, the Oregon Plan has the following steps (Stewart and Nelson 1996):

Assemble a Team that represents local stakeholders

Delineate the protection area (obtain certification from OHD)

Inventory potential contaminant sources within the protection area

Team develops a management plan

Team develops a contingency plan and a new water supply plan

System obtains DEQ plan certification

Oregon has developed a Guidance Manual (Stewart and Nelson 1996) that is designed to help systems or communities through the process of plan development. The manual provides technical assistance in all of the above steps and, particularly in the management chapter, provides communities with a number of options with respect to how the local residents can protect their drinking water source.

With the help of EPA funds, Oregon was able to conduct demonstration projects in several Oregon communities. Technical demonstration projects involving methods to do the delineations (see below) were accomplished in Boardman (Morrow County), Klamath Falls (Klamath County), and Springfield (Lane County). Testing the utility of the Guidance Manual and the incorporation of agricultural practices in the process was the goal for plan development demonstration projects in Coburg and Junction City (Lane County).

One of the many feedback items received from communities during this process was that a successful plan would be one that depended significantly on education, both in terms of providing a better understanding of how the local groundwater-surface water system worked, but also in terms of how everyone can have an impact on water quality and the potential relationship between surface activities and local water quality. Another issue was that the term "wellhead protection" is misleading, often interpreted as a protective structure, e.g., fence or building, around the well itself. The average citizen did not make the connection between "wellhead protection" and resource protection. Accordingly, Oregon has followed the lead of other states, e.g., Utah, and has changed the program name to "Drinking Water Protection." This term will be applied to the protection of drinking water resources whether derived from groundwater or from surface water.

DELINEATION OF A GROUNDWATER RESOURCE

The purpose of the delineation phase is to identify the critical area, the Drinking Water Protection Area (DWPA), that supplies drinking water to a community or other water system. For groundwater sources, we are identifying the area on the surface that overlies that part of the aquifer that supplies water to the well or spring.

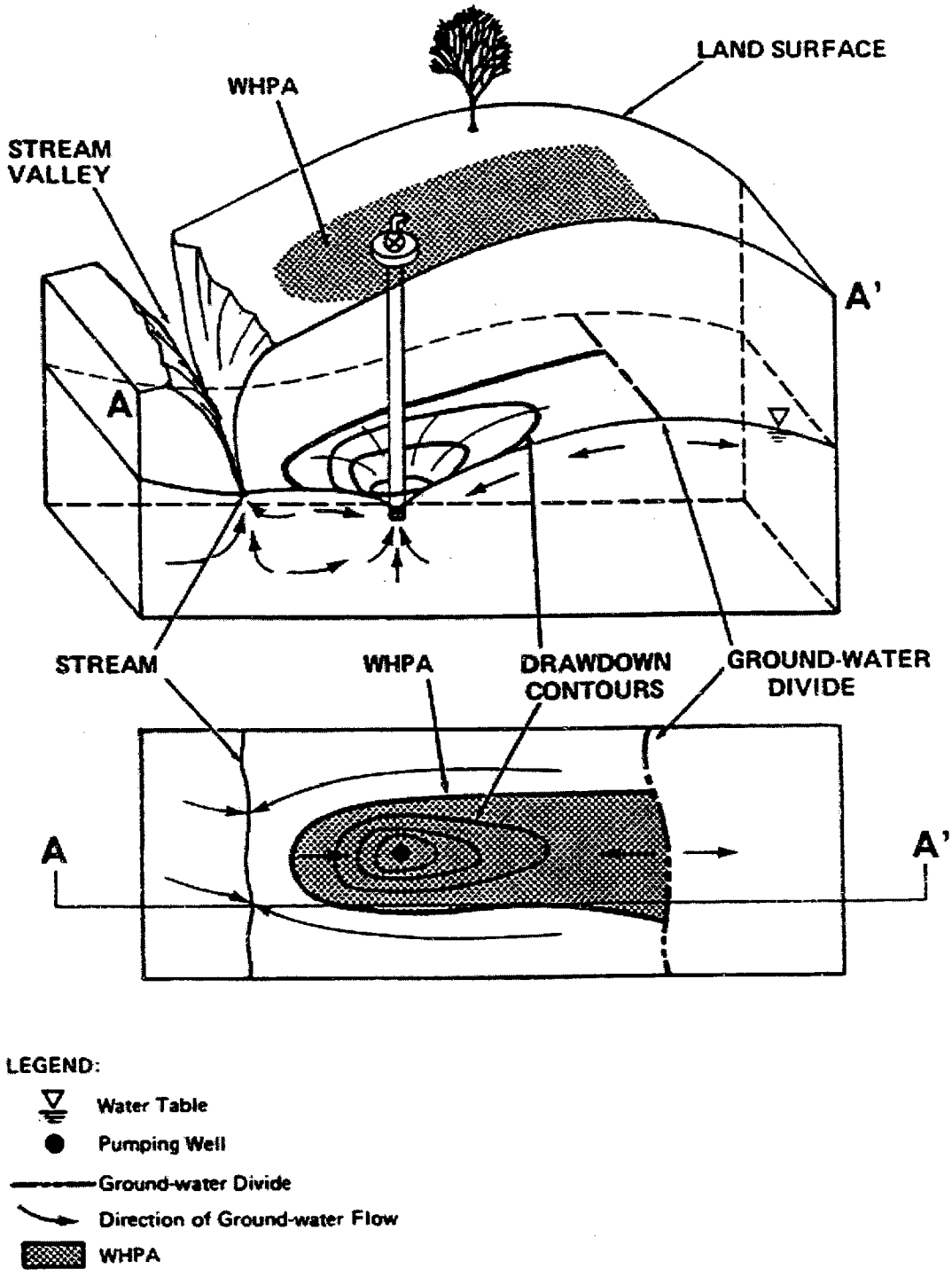

Figure 9. Diagram illustrating the relationship between the drinking water protection area (WHPA) and the capture zone of the well (Figure from USEPA (1987)). In the upper diagram the effect of the pumping well on the regional water table can be seen. The drawdown cone perturbs the direction of groundwater flow in proximity to the well creating a capture zone shown as the stippled area in the lower diagram. Any water molecule, and any dissolved constituent, within the boundaries of the capture zone will ultimately travel to the well. The drinking water protection area represents the land area directly above the capture zone. Any contaminant released within that area could migrate downward to the water table and follow the groundwater flow within the capture zone to the well. Management should be focused within the drinking water protection area.

Figure 9 is a 3-dimensional block diagram that demonstrates the relationship between the DWPA and the aquifer. In the upper part of the figure, a pumping well is shown. Note that the water table is drawn down in the vicinity of the well as the aquifer yields water to the well. This contributes to the formation of the capture zone, or zone of contribution (ZOC) of the well. The ZOC extends upgradient, the direction from which groundwater is moving, to some boundary, e.g., a geologic contact with relatively impermeable rock, a groundwater divide, a river, etc. In the bottom part of the figure, the ZOC is shown in map view as the stippled area. All water within the ZOC will eventually move downgradient and into the well. Obviously any contaminant that is in the ZOC may also be transported to the well. The DWPA is the area on the surface directly above the ZOC. Within the DWPA, a contaminant that is released may be transported down to the ZOC and eventually into the well. The potential of this is clearly site- and chemical-specific; however, the DWPA is defined conservatively, based on the average velocity of groundwater within the aquifer.

For water systems serving a population of less than 500, a simple volume calculation is used, whereas for larger systems, a hydrogeologic conceptual model and the use of more complex modeling tools, e.g., analytical and numerical methods, are used (Stewart and Nelson 1996). The capture zones for springs are accomplished by hydrogeologic mapping to determine what geologic control exists for that spring and how this feature occurs in the subsurface. All the methods require the estimation of hydrogeologic characteristics of the aquifer.

The size and orientation of the DWPA depends on the pump rate, aquifer characteristics, e.g., hydraulic conductivity, hydraulic head, thickness, effective porosity, aquifer boundaries and level of recharge and discharge, the hydraulic gradient, and the time-of-travel (TOT) used.

The ZOC may be a large area, potentially being kilometers in length as it defines the total aquifer area that is involved in supplying water to the well. For practical purposes, Oregon selected an arbitrary upgradient boundary for the DWPA within the ZOC of a 10-year TOT, based on the average velocity of groundwater flow. Experience thus far indicates that this translates into a DWPA length varying from ~150 meters to 1,500-3,000 meters. In addition to the 10-year TOT, Oregon also asks that water systems delineate the 2-year and 5-year TOTs as well in order to facilitate management. As an example, evidence supports that some viruses may persist in groundwater for up to 2 years. The 2-year TOT will provide, then, a conservative estimate of the area around the well where if viruses gain access to groundwater, they may impact water quality at the wellhead.

THE 1996 AMENDMENTS TO THE SDWA: SOURCE WATER ASSESSMENTS

The 1996 Amendments to the SDWA require that the states develop and implement a program which results in a source water assessment being conducted for each public water system in the state. The assessment is to consist of three components: a delineation, an inventory of potential contaminant sources, and a susceptibility analysis to determine the relative risk associated with those sources. Funds to support this effort are available through set-asides from the State Drinking Water Revolving Fund. It should be noted that the source water assessment program mandated in the 1997 Amendments does not address protection directly. Rather, the program is designed to collect information that water systems can then use to develop management strategies that would serve to protect drinking water sources. Oregon will use its existing drinking water protection program, a.k.a., wellhead protection, to accomplish the delineations for groundwater-based systems. These efforts, as described above, involve hydrogeologic evaluations of the aquifer characteristics and result in a time-based subset of the capture zone being identified.

Delineation methods for surface water sources under this program have not as yet been determined. USEPA (1997) requires a topographic delineation be accomplished for any surface water drinking water source that may involve any or all of the following:

Watershed: the entire catchment area of a stream

Subwatershed: the catchment area for a tributary within the stream system

Watershed Area: the topographic boundary of catchment upslope from the water system's intake (Figure 10)

Many intakes are located within a drainage basin, and inventory and future management activities are most efficient if they focus on the area that may actually impact the drinking water quality. Clearly, the watershed area is directly related to the water system's intake and should be given the highest priority in terms of developing strategies to protect the source.

USEPA (1997) further recommends that enhanced topographic delineations be accomplished within the watershed protection areas, analogous to the variable TOTs within the drinking water protection areas for groundwater systems. The purpose would be to prioritize the watershed area for inventorying potential contaminants and implementing management strategies. The techniques recommended for enhanced delineations within the watershed area include the following:

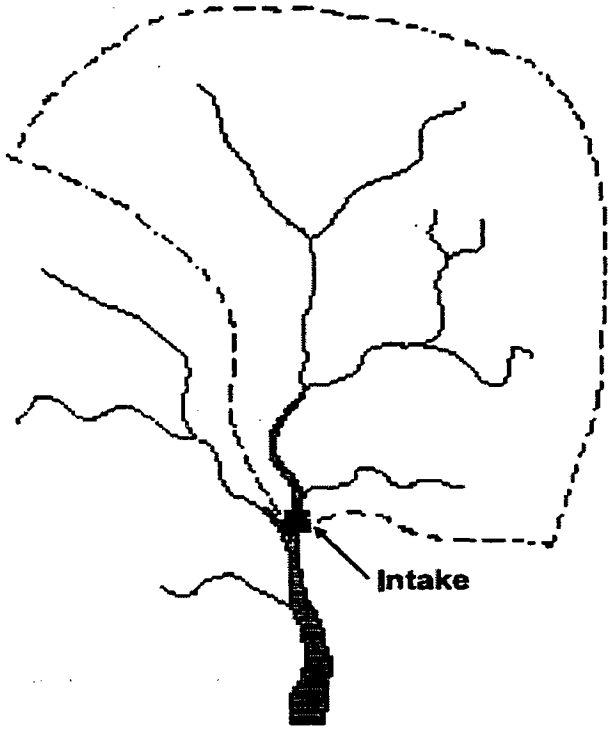

Figure 10. Diagram of a watershed area (Figure from USEPA (1997)) which is the area topographically up slope from the public water system intake within the watershed. Surface water within the watershed area will drain to the stream or its tributaries and move to the intake area. Management strategies to protect surface water quality are focused within the watershed area.

Buffers/Setbacks along the stream

Modeling of groundwater discharge and surface water runoff

Time-of-Travel within the stream

Mixing/Dispersion

Surface water buffers and setbacks are zones that are generally 15 to 60 meters in width (USEPA 1997) surrounding the surface water source. The actual width should be based on site-specific information including topography, stream size, soil type, and land use. The purpose of this zone is to reduce the impact on water quality of the land use immediately adjacent to the stream by enhancing the infiltration of sheetflow and promoting natural filtration of sheetflow as the water passes through the vegetation enroute to the stream. It is envisioned that buffer zones or setbacks have been defined under other programs, e.g., riparian areas established under the Oregon Forest Practice rules in order to protect fish habitat (e.g., Hairston-Strang and Adams 1997), conservation buffer zones established under guidelines of the National Resources Conservation Service to minimize erosion, or similar features designed to mitigate the impact of storm water runoff, will largely apply to drinking water protection.

Modeling of potential contributions from groundwater discharge and surface runoff is a time- and data-intensive effort that is useful in estimating various chemical loading rates to surface water. USEPA (1997) recommends that the watershed protection area be divided according to land use, e.g., residential, commercial, industrial, agricultural, forest, etc. Based on characteristics associated with the contaminant, the local topography, runoff, sediment yield, etc., the potential loading rate can be estimated for various land use parcels within the area and protection strategies can be developed accordingly.

The last two bullet items above are not designed to identify specific areas within the watershed area for management purposes; rather they provide the community with information regarding designing a response to a spill event. Time-of-Travel within the stream system provides the water system with knowledge of how long it will take a chemical release to reach the intake from a given point within the watershed area, i.e., how long can the system continue to draw water from the stream before the contaminant arrives at the intake.

Mixing/Dispersion determinations are directed at identifying how mixing within the stream will influence the concentration of a given constituent at the intake. As a result of flow characteristics within the stream, a given constituent is dispersed or scattered as flow continues downstream. As a result, the concentration of a contaminant will decrease in the stream water with distance traveled from the loading source. For a given release, the concentration of the constituent at the intake will be a function of the volume, concentration, and loading rate of the release; stream flow volume; and stream characteristics, including slope, stream flow regime (pool versus riffle), stream bed roughness, and channel depth and width (Lee 1995). The stream flow and stream characteristics, site-specific for a given stream and stream reach, allow the prediction of the contaminant concentration and the shape of the concentration peak as it passes the intake for a given loading event, e.g., a "spike," producing a short-duration, high-concentration event or a broader lower peak, producing a long-duration lower concentration event.

Both the average stream velocity and mixing/dispersion determinations can be determined by dye-tracer studies (Hubbard et al. 1982, Lee 1995). As indicated above, the characteristics that influence velocity and mixing vary from stream to stream and determinations based on one stream cannot with confidence be directly applied to another stream, although general relations between stream discharge, gradient, and stream velocity do exist. Velocity and mixing parameters have been determined by tracer studies along various stream segments in the Willamette River Basin (Lee 1995) and along a segment of the South Umpqua River (Laenen and Woo

1993). Similar data are not readily available, however, for many other streams in the state.

CONJUNCTIVE DELINEATION

There are many hydrogeologic settings in which there is significant hydraulic connection between groundwater and surface water, e.g., where a river flows across fractured bedrock that contains groundwater, in a river valley where a stream is flowing through alluvial deposits, etc. EPA recommends that in those cases, delineations be conducted in a manner that recognizes the contribution of both groundwater and surface water to a system's drinking water.

For groundwater-based systems that have been recognized as in hydraulic connection to surface water (see above), it is important to recognize that a portion of the water supplied by the well is derived from the stream. Consequently, activities that occur upstream in the watershed, affecting stream water quality, may eventually impact the water being extracted by the well. As discussed above, this connection may be natural, a result of stream stage or natural hyporheic circulation (Stanford and Ward 1988), or may be induced, the result of the drawdown cone reaching the stream. Clearly, the induced connection may be seasonal, depending on the pump rate and duration. USEPA (1997) considers that the conjunctively delineated source water protection area for a hydraulically connected groundwater source would include the drinking water protection area for the groundwater source, delineated as above, plus the entire watershed upstream of the intersection of the drinking water protection area with the stream.

Groundwater discharges to surface water along stretches of most streams in Oregon and during low flow periods, groundwater base flow may supply the bulk of stream discharge. Conjunctively delineating a source primarily supplied by surface water requires the identification of the area overlying that part of the aquifer that is supplying base flow to the stream. It is likely that a significant portion of that area will already be contained within the watershed protection area; however, regional groundwater flow does not always flow in the same direction as the surface slope, the time-of-travel for groundwater through the basin may be greater than 10 years, and topographic and groundwater divides do not necessarily coincide (USEPA 1997). In larger basins, estimates of groundwater flow velocity will have to be made in order to identify how far upgradient the conjunctive delineation should apply.

It is evident that the conjunctive delineation will pose both technical and managerial challenges to the development of assessments and drinking water protection plans. In Oregon's current drinking water protection program, groundwater sources in hydraulic connection with surface water are expected to develop contingency plans designed to protect their aquifer source should a release occur higher in the watershed of the stream with which their source is in hydraulic connection (Stewart and Nelson 1996).

SUSCEPTIBILITY ANALYSIS

USEPA (1997) defines susceptibility as the potential for a public water supply to draw water contaminated by inventoried sources at concentrations that would pose concern. The term "vulnerability" is often used in the same sense and implies that the risk of contaminated water occurring at a public water supply is a function of (1) the presence of a source of the contaminant, and (2) the aquifer's sensitivity. Aquifer sensitivity is an indication of the probability that a contaminant released at the surface will travel downward to the aquifer. Sensitivity is controlled by hydrogeologic and hydrogeochemical factors that for groundwater sources include the depth of the water-bearing zone, thickness and permeability of the vadose zone, the amount of rainfall and/or irrigation, and the chemical characteristics of the contaminant of concern, e.g., sorption characteristics and persistence.

A number of regional to site-specific methods for determining aquifer sensitivity have been devised, e.g., USEPA (1991a), USEPA (1991b), OHD (1992), etc., but virtually all of these require site-specific data in order to provide estimates of the values of the controlling parameters given above. State-wide assessments, useful for prioritizing areas within the state, are not designed to be predictive at the scale of a single well. Similar site-specific information is required to address the sensitivity of a stream segment to runoff: slope, character of the surface, vegetative cover, etc.

The utility of the susceptibility analysis is that it provides a management tool for the community or water system to prioritize its efforts and resources so as to address those areas within the Drinking Water Protection Area where risk to drinking water quality is the greatest. This can be accomplished by overlaying a map showing where the potential for infiltration to groundwater or runoff to surface water is the greatest with a map showing potential contaminant sources ranked according to general or real risk. Another utility comes from being able to tailor particular best management practices at a specific facility to fit the sensitivity of the underlying aquifer or the adjacent stream.

INVENTORY OF POTENTIAL CONTAMINANT SOURCES

After the drinking water protection area for either a groundwater or surface water source has been identified, an inventory of potential contaminant sources is conducted. It is important to emphasize the term potential in

this case. Based on national data, as well as from Oregon, we know that statistically, contamination events are more likely to occur associated with some land use activities than others. The Oregon Wellhead Protection Guidance Manual (Stewart and Nelson 1996) provides further discussion of potential contaminant sources and provides worksheets that facilitate the inventory process. Recommended sources of information for the inventory include:

Zoning map to identify areas of specific land use

Aerial photographs to provide, depending on the date of the photograph, information about the locations or facilities now or in the past

Identify historic land use and activities using aerial photographs or anecdotal information from residents

Existing permits/records from the Fire Marshal, DEQ, WRD, ODA, etc.

Informal inventory using Guidance Manual forms

These potential sources should be plotted on a map and ranked according to their potential risk to water quality. This relative risk information is available in the Guidance Manual (Stewart and Nelson 1996) but it must be understood that this is a general risk ranking that assumes that the facility is at present not implementing any mitigation measures. The relative risk ranking provided in the document may not apply to a specific facility on the ground and that site should never be characterized specifically by the relative risk ranking. The ranking should be considered as a prioritizing tool only.

We have found that a map showing the DWPA and various facilities within the DWPA that could potentially cause a water quality problem is a useful planning tool for communities. The inventory map displays those land uses that are operating within the well's DWPA or within the watershed protection area. With that information, the system or community is in a better position to make decisions about land use and water quality.

MANAGEMENT WITHIN DRINKING WATER PROTECTION AREAS

The primary objective of management strategies within a Drinking Water Protection Area is the reduction of contamination risks. It is understood that elimination of risks is not possible and that there are other considerations, including economic implications and private ownership issues that may need to be considered. Importantly, the management strategy is developed by a local Team that contains a representative cross section of local stakeholders. The state's guidance for groundwater systems (Stewart and Nelson 1996) as well as other publications (e.g., Witten and Horsley 1995, USEPA 1994, etc.), provide directions for management strategies and examples of those used elsewhere, but the final decision with respect to which strategy or strategies best fit a given community is made locally. The types of management strategies that may or may not be used by a community are listed below:

Public Education/Notification: notifying individuals who live or own property in the drinking water protection area of the potential sensitivity of the area and the relation between surface activities and water quality.

Sign Installation: signs placed on all roadways entering the drinking water protection area informing travelers of the sensitivity of the area.

Water Conservation Programs: smaller amounts of water use for groundwater systems means lower pump rates, smaller areas to protect and less chance of moving contaminants into the area.

Public/Private Partnerships: Agreements between the community and private business, commercial, industrial, and agricultural communities, designed to protect drinking water are mutually beneficial.

Hazardous Waste Collection: Providing a means for small businesses and households to properly dispose of hazardous wastes significantly reduces the risk to the water supply. The Oregon DEQ can provide assistance in establishing a "Hazardous Waste Collection Day" in the community.

Spill Response Plans: Developing an integrated response approach, that includes the community's water supply management, to spills occurring within the Drinking Water Protection Area, significantly reduces the risk to the water supply.

Zoning Ordinances: Identifying the Drinking Water Protection Area as an overlay allowing the community to use a special permitting process to monitor new building applicants and some chemical uses within the area.

Property Purchases/Donation Program: A community obviously has more control over land use within their own property boundaries.

Septic System Upgrades/Maintenance Program: A septic system density of more than one per acre may cause problems associated with nitrate. Encouraging proper use of septic systems, e.g., no disposal of household chemicals, and proper maintenance will reduce the risk to local water supplies.

Special Chemical Use/Transport Prohibition: Prohibiting the transport of high-risk chemical compounds within the Drinking Water Protection Area to reduce the risks of spills.

Potential Source Restrictions: Communities may want to consider prohibiting the placement of some high-risk potential contaminant sources within the Drinking Water Protection Area, e.g., dry wells, underground chemical storage tanks, landfills, etc.

Education is a very important tool in drinking water protection, and there are a number of programs available for the general public, businesses, industry, and agriculture. For example, the Oregon DEQ provides technical assistance to businesses through their Waste Reduction Assistance Program, and OSU Extension agents are available to advise farmers on best management practices for the particular crops that are being grown. The DEQ and OHD can provide information that a local community can access or use in local schools to provide information directly to community residents.

Community Drinking Water Protection Plans are submitted to the DEQ for review if the community wishes to obtain state certification. The state's program functions best if the agencies are given an opportunity to contribute to the plan development early on. Certification occurs if the measures that are to be implemented by the community will significantly reduce the risk of contamination to their drinking water supply.

DEVELOPMENT OF OREGON'S DRINKING WATER PROTECTION PROGRAM

As discussed above, Oregon is required to develop and implement a Source Water Assessment Program. Although the existing Drinking Water Protection Program can be applied directly to groundwater systems, there are some significant questions concerning delineation of surface water source areas, conjunctive delineation, susceptibility analyses, prioritization, and coordination with other agencies, groups, and programs that have not been answered at the time of this writing. The state will convene a citizen's and technical advisory committee, the Drinking Water Protection Advisory Committee (DWPAC) that will address these issues.

It is the agencies' (DEQ and OHD) intent to develop a program that balances to the extent possible, a scientifically based and technically defensible strategy for delineation and susceptibility determination with a strategy that can be implemented by communities. We will make use of existing programs with common goals and objectives and will seek input from those state and federal agencies, as well as local interest groups, that have procedures in place that address water quality issues.

SUMMARY

The approach to the potential of contamination of drinking water supplies at the federal and state level has shifted from reaction to prevention. The cost effectiveness of preventing contamination from happening versus the expense of investigation and mitigation of a contaminated resource is well documented. In response to the 1986 Amendments to the Safe Drinking Water Act (SDWA), Oregon developed and implemented a voluntary Wellhead Protection Program which provided a mechanism for groundwater-based public water systems to protect their resource.

The 1996 Amendments to the SDWA require that the states develop and implement a program that will result in Source Water Assessments, consisting of delineating the resource, inventorying potential contaminant sources, and conducting the susceptibility analysis, being accomplished for public water systems, both groundwater- and surface water-based. The Oregon Department of Environmental Quality and Oregon Health Division will cooperate in this project, convening a Drinking Water Protection Advisory Committee (DWPAC), representing relevant stakeholders, to help design the program and its implementation.

Oregon's Drinking Water Protection Program for groundwater, i.e., the Wellhead Protection Program, will be used to satisfy the requirements of the 1996 Amendments directed towards groundwater. The DWPAC will provide direction in designing the Source Water Assessment approach to surface water and to ensure that existing agency and interest group programs are integrated into the effort.

The agencies will also work towards the utilization of the data collected during the assessment program for the development of actual protection plans. Participation by communities and water systems in this effort will be voluntary. Although the state will provide technical assistance to communities or water systems in developing Drinking Water Protection Plans, the plans themselves will be put together by local teams that represent a cross section of local interests.

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Whose Watershed Is It? Eulogizing the Columbia River Salmon or How We Ran All the Red Lights on the Road to Extinction

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Nearly a dozen books have been published on the Columbia River in the past 36 months. It is a remarkable outpouring considering fewer than a dozen books have been written on the Columbia for the past 36 years. Why this sudden interest in this Columbia Basin? Could it be that we have finally lost the Columbia River? These authors think so. These new books all have one thing in common. They read like eulogies.

This is not the first warning we've had: Joe Cone's *The Northwest Salmon Crisis: A Documentary History* contains documents warning of the river's abuse and the salmon's decline that date back to the late 1800s. As it turns out the authors were not Cassandras. They were prophets.

There were warnings in Richard Neuberger's pieces in the *Sunday New York Times Magazine*. The 1950s articles celebrated man's engineering genius at harnessing nature.

Oral Bullard wrote a pungent warning on the state of the stocks in his *Crisis on the Columbia* in 1965. Antony Netboy explained the causes of declining stocks in his classic, *The Salmon: Their Fight for Survival*, in the 1970s.

The turn of the century warnings were yellow lights. Bullard's and Netboy's books were red lights. We ran them all.

We celebrated Man's Dominion over Nature's River. If anyone stopped to observe the effects on natural ecosystems or even the specific fish we were trying to protect they were told technology will solve those problems too. Hatcheries, fish ladders, bag limits, sure we could do it and have fish and hydropower both.

Nothing succeeds like excess. The ritual incantations became a sacred litany justifying more and more dams until it became evident the Columbia Basin fish runs were in a steady decline.

It was not a straight line decline. We kidded ourselves about cycles and recoveries, the effectiveness of regulation and the public's willingness to pay for put and take fisheries in perpetuity.

Oregonians may also have been misled by their own success at environmental protection. Oregon is the state that cleaned up the Willamette River. Criticizing the Willamette as an open sewer got television commentator Tom McCall elected governor in 1963. McCall is, by common consent, one of Oregon's most effective modern governors.

McCall campaigned on cleaning up the Willamette, choked by untreated pulp mill waste and municipal sewage. McCall established Oregon's environmental ethic —if you use it clean it up before you put it back. This applied to governments as well as private business—the air as well as the water.

Oregon had help cleaning up its waterways. Because of McCall's foresight, Oregon had ambitious plans drawn up for regional sewage treatment systems when Congress passed the Clean water act in the early 1970s with its 75 - 25 cost sharing provision. Oregon planned for growth. Most of Oregon's existing municipal sewage treatment and water treatment capacity was financed by that 75-25 cost sharing. The state is still growing at 3 to 5 percent a year. The federal revenue sharing will not be there to finance the next round of growth—an important consideration for watershed management.

Another Oregon Governor, Bob Straub, invented the idea of the Willamette Greenway to protect the river's beds and banks from incompatible development. Taxpayers paid money to buy large blocks of land along the Willamette for public parks, until a shortsighted legislature put an end to the practice at the behest of developers and farmers, permitting further hemming in the river in both urban and rural areas.

The cleanup and protection of the Willamette is regarded as one of Oregon's stellar public achievements. So you can imagine my surprise when biologists on the senior staff of the Oregon Department of Fish and Wildlife told me last year they believed the Willamette was lost as fish habitat.

We put too much trust in expert opinion. In the 1930s, 40s, 50s, 60s, and 70s, we dammed hundreds of miles of fish habitat in the Columbia Basin because professional fish biologists assured us hatcheries would keep sports and commercial fishing viable. Today a courageous few of these biologists, now in retirement, admit they were wrong. They admit they did not understand what they were doing to the rivers.

Despite McCall's ambitious efforts and Straub's farsightedness we have lost the Willamette and for the same reason. We did not know what we were doing to the river. We thought clean water and protecting the beds and banks would be enough to ensure fish habitat. It was not. We have hemmed the Willamette River in with dams and urban and agricultural development; it no longer has the hydrology to renew its fish habitat. We diminished its carrying capacity without knowing it. We deluded ourselves with the argument we could have development and a natural river at the same time. We did the same thing to the Columbia with the same lack of knowledge. The problem isn't limited to fisheries.

"Silviculture," former Bohemia, Inc. CEO Dick Tinney once told me, "is science. Forestry is politics."

Politics is out of fashion these days. Science is in. We have convinced ourselves that science with its empirical method of analyzing problems is sound, safe, objective, more reliable than politics. We are only learning the limits of science. Science as we know it has not been around very long. Charles Darwin published his revolutionary book *Origin of Species* in 1859—the same year Oregon became a state. Evolution spelled the end of biblical absolutism and the world found its new guru—the scientist complete with white coat and research lab.

Various interest groups hire scientists to assure us their political agenda is scientifically based. We believe. Fish runs damaged by hydroelectric dams can be replaced by fish hatcheries. Electricity generated by nuclear energy will be so cheap it will not be metered. Let people choose their own utility, and electricity will be cheaper. Deregulation of the airline industry will make flying everywhere cheaper and more convenient. Clearcutting simply imitates natural fires. The forest will be better for it. We believe because we want electricity, wood, airfare wars, jobs, and the standard of living that comes with them.

Today retired biologists admit they were wrong about fish hatcheries. Nuclear energy is the most expensive electricity. Nuclear plants did not outlive the bonds borrowed to build them and we are still paying to solve the waste disposal problem. It is not possible to get cheaper electricity in a region of the country with the lowest electric rates in the nation. Cornell Professor Alfred Kahn says the only thing wrong with airline deregulation is that people refuse to behave according to his theory. The result of clearcutting is fewer mills, lower wages, record profits for the companies that remain, socio-economic problems for the communities once dependent on the public forests and, of course, habitat degradation.

Again the public calls on scientists for answers to social and environmental problems. A few courageous scientists are urging humility. Dr. Jerry Franklin has spent 40 years in the Forest Service and academia at Oregon State University and the University of Washington. He is a pioneer in old growth forest research. Franklin's work forced industrial foresters to change their way of thinking.

It was an axiom of industrial forestry that old growth forests were "dead, dying, and decadent" and "biological deserts." Franklin's pioneering research, much of it begun 40 years ago in the H.J. Andrews Experimental Forest in the Willamette National Forest east of Eugene, proved clearcuts were biological deserts and old growth forests were genetic safety deposit boxes. Some of Franklin's critical colleagues never forgave him for successfully overturning their orthodoxy.

"The Forest Service viewed scientists as harmless people who didn't cost a lot of money and occasionally came up with something useful. It kept intellectuals off the streets," chuckles Franklin. But managers picked and chose the expedient scientific conclusions that supported their "preformed" decisions. Scientists, said Franklin, were kept carefully isolated from policymaking.

Litigation changed all that. If the Forest Service ignored their scientists, environmental lawyers did not. Forest Service managers were suddenly confronted with their own scientists testifying under oath for critics of federal forest policy.

"Their attitude toward scientists went from benign neglect to open hostility," said Franklin. The Forest Service tried to control scientists urging them to become part of the management team.

"You can't control science," warns Franklin. "Science will go where science will go." Forest Service managers decided they should at least be knowledgeable about what their scientists were learning.

What Franklin called the "Spotted Owl train wreck" put scientists in the pivotal role of "defining the envelope of legality" when U.S. District Judge William Dwyer decided the Forest Service did not have a scientifically credible forest management plan and enjoined all logging until the agency came up with one. Politics delayed that decision for nearly half a decade. President Bill Clinton's Forest Plan passed judicial muster and Dwyer dissolved his injunction.

Franklin is uncomfortable with this pivotal role for scientists. Franklin was a member of the "Gang of Four" scientists who drafted the ecosystem management approach that became part of the Owl Recovery Plan required by the Endangered Species Act. He believes scientists who have gone from isolation on the fringe of policymaking to being all powerful are now moving to a more appropriate role as collaborators in a partnership of resource managers and stakeholders. Franklin is advocating a process called "adaptive management" these days.

"We will never get to a place where we learn all there is to learn and discover an ideal way to manage the forests

from now on," warned Franklin. "How did my generation get that idea?"

"We must admit we will learn new things. That it is not threatening to use what we learn to change. All of us will have their oxen gored. All of us will be challenged to give up their old beliefs," warned Franklin. "Academics are no better than anyone at putting aside old, closely held beliefs," said Franklin wryly.

"When I earned my degree in forestry at Oregon State dispersed patch clearcutting was orthodoxy. Now we know it was wrong," said the man who did much of the research that overturned the orthodoxy. "Dispersed patch clearcutting breaks up the forest cover and creates too much edge effect. It was wrong."

Franklin angers the environmentalists who just want to stop logging. He believes "you can't save it all." But timber industry lobbyists get no comfort from Franklin's advice on how to proceed with experiments in forest management.

"We should be cognizant of the limitations of our knowledge of forest systems," said the man who is still a pioneer in learning about forest systems.

Describe Jerry Rudy's Zone of Ignorance. We are operating vigorously in that zone of ignorance today.

Today Northwest coastal coho salmon runs are listed as threatened in the Southern Oregon/Northern California Evolutionarily Significant Unit and a species of concern in the Northern Oregon Evolutionarily significant unit—and you thought bioregions were jargon! This may turn out to be one of the most artfully sophisticated compromises in the history of the Endangered Species Act—certainly if you are interested in results instead of litigation.

The compromise gives added federal clout to a region where much of the problem is on federally owned land and where Indian tribes still are interested in fish instead of video poker. In the Northern part of the coast where the largest problem is habitat degradation by private land owners the solution is left to state government which has more authority over private land. The compromise avoids the crisis atmosphere of the endangered listing and the single species solutions of the Endangered Species Act.

The coastal coho compromise forces the timber industry and agriculture to put its money where its lip service has been for decades on environmental stewardship. I am not optimistic about the state and private efforts. Douglas County is still trying to build porkbarrel dams. There is still opposition to removing Savage Rapids dam on the Rogue.

And all the talk about preserving salmon runs gives lip service to but otherwise carefully skirts the consequences of the declining Columbia Basin salmon runs with all their implications. The question is whether any salmon recovery plan has any chance of saving the wild salmon on a river in the Columbia's condition. Will practical politics allow the changes in the river that are necessary for salmon survival? What are the implications of so-called utility deregulation on salmon. Utility reregulation will make older more remote hydroelectric dams obsolete. Are resource managers ready for this opportunity?

The Endangered Species Act has never been applied to a situation quite like this. The Act is usually applied in situations where development has slowly, inadvertently threatened extinction. Never before has a deliberate, premeditated decision to extinguish a wild species in exchange for a domesticated replacement been overturned when a new generation had second thoughts.

The price of these second thoughts will be high on the Columbia and we do not know whether any recovery effort can be successful.

If I were a Governor or a legislator I would ask two questions. 1. Can Oregon, acting alone, make any difference restoring the Columbia fish runs? 2. Is restoration achievable at any cost?

There are no real answers to these questions on the Columbia. Everyone wants what they call their property rights in the watershed, but no one is willing to accept responsibility for their contribution to the decline of the whole ecosystem. Instead we fight over "Whose Watershed Is It?"

We have been here before. We had nearly the same fight over the water in this watershed about 100 years ago. Prevailing water law followed the English common law called the riparian doctrine. Water in a stream belonged to the riparian owner to use as long as the stream flow was not diminished. Adequate water for upland users came from wells. No one was free to enrich himself by diverting or impounding the flow of water. The water—like today's watersheds—belonged to no one and everyone. It belonged to a benevolent God himself. This English system was widely adopted in the eastern United states which, like England, had the dependable, abundant rainfall the law required to work.

Like any number of legal concepts, the riparian doctrine did not work in the arid west. The gold rush broke it. The miners in the Sierra foothills, the Colorado goldfields, and the Oregon river canyons believed that water, like the gold they found, was in the public domain—theirs for the taking. They needed water for their sluice boxes. They took it without a second thought for anyone downstream. The folks downstream objected a might. The miners' lawyers responded with the legal doctrine of prior appropriation—first in time is first in right. The history of the water in our watershed is the continual adaptation of this legal doctrine invented to justify the miners' exploitation of water to the changing needs of society.

The fact that it rains at the wrong time of year in the west has led to the huge federally subsidized hydraulic society that John Wesley Powell warned about in his famous 1879 *Report on the Lands in the Arid Region of the United States*. Powell, a rugged individualist typical of his era, warned that the practical problems of bringing water to the arid lands of the western United States would make individuals dependent on religious organizations (he had just seen what the Mormons had accomplished in Salt Lake City) or dependent on large corporations or the government that built the public works necessary to bring water to the land. He was not optimistic about preserving traditional American values under such conditions. Powell was another prophet ignored.

Ironically, far from objecting to the heavy hand of government, modern Western water users demand that governments referee the regulated use of water to protect the property rights of those downstream.

It is unfashionable today to encourage the role of government, but it should be clear to everyone in this room that continued competition between watershed stakeholders claiming their rights will destroy the watershed. While voluntary cooperation is considered politically desirable today, there is simply no history of cooperation —voluntary or otherwise—among these old antagonists.

I believe public pressure for watershed restoration will eventually produce a consensus for government to serve as a referee over land uses in watersheds much as government now referees the use of the water in the watershed. After all, we all live downstream.

Restoration plans may be a hard sell because there is evidence the public does not yet understand the full dimensions of the problem. The results of a recent public opinion survey of 500 Oregon coastal residents conducted by Oregon Sea Grant anthropologists Cortland Smith and Jennifer Gilden at Oregon State University reveal a wide gulf between their opinions and the opinions of scientists over what has to be done to restore salmon runs.

The surveyed coastal residents believe the state of Oregon should lead salmon restoration efforts. They want private landowners compensated for protecting and restoring salmon. Coastal residents have no more than moderate confidence in organizations dealing with salmon. Federal fish and wildlife agencies and OSU Extension Service fared better than environmental groups and local government planners who fared better than federal courts or Congress.

Coastal residents polled believe reducing predation by seals and sea lions, increasing hatchery production, and eliminating ocean drift net fishing are very important to salmon restoration. These views vary substantially from the views of professional biologists responsible for salmon restoration.

This wide variance in opinion may be explained by the last finding in the survey. Sixty-two percent of the coastal public receives its salmon information from radio and television and 60 percent from word of mouth. Those are the two most frequent sources of information. Both are notoriously unreliable.

While the impulse is to put limited funds into watersheds where native runs are most likely to survive, the utilitarians will be tempted to make national sacrifice areas out of the more seriously damaged watershed and avoid the cost of restoration. We should not allow them to get away with that.

The Northwest has two places where restoration plans can be demonstrated and results measured fairly quickly on a smaller scale—The Klamath River in the county of Jefferson and the Elwah on the Olympic Peninsula. Many of the principles discussed today should be tested in these watershed before they are applied to larger landscapes. It is, after all, our watershed.

A COLUMBIA RIVER READING LIST

Compiled by Russell Sadler

This is an idiosyncratic list of the dozen books published on the Columbia River over the past several years. I have added a few golden, moldy oldies in honor of some people who saw the problems before most of us.

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INTERDISCIPLINARY RESEARCH AT NORTHWEST WATERSHED RESEARCH CENTER AND REYNOLDS CREEK EXPERIMENTAL WATERSHED

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POSTER ABSTRACT

Long-term landscape-scale research is fundamental to full understanding of hydrologic processes and dynamic relationships over broad spatial and temporal scales. The Northwest Watershed Research Center (NWRC) and Reynolds Creek Experimental Watershed (RCEW) were established in 1960, to conduct research addressing water supply, flooding, and erosion in rangelands where seasonal snow and frozen soil conditions strongly influence hydrologic regime. The 234 km^2 Reynolds Creek basin (RCEW) in the Owyhee Mountains 70 km south of Boise, Idaho, was selected as an outdoor hydrologic laboratory for the mountainous rangelands of the interior Pacific Northwest, reasonably representing a landscape with high relief and diversity of geology, soils, aspect, vegetation, and land use. The elevation range of RCEW is 1,098 m to 2,254 m. Mean annual precipitation varies from 23 cm at the lowest elevations to over 110 cm at the headwaters, where over 75% of annual precipitation comes as snow. An intensive precipitation and streamflow measurement network includes 18 dual-gauge precipitation sites, 5 comprehensive climate stations, 7 snow courses, and 9 stream gaging stations within RCEW. In this fourth decade of research, hydrologic monitoring has been improved to embrace state-of-the art data acquisition, real-time telemetry, and relational database archiving. Research is conducted within this monitoring framework under two primary programs: *Characterization, Prediction and Scaling of Watershed Processes and Streamflow*, and *Conservation, Restoration and Utilization of Rangelands*. Current studies include: stochastic climate simulation model development and application to mountainous terrain; developing algorithms and model components to predict infiltration and runoff from snowmelt and frozen soils; determining interactions of rangeland vegetation and soils with surface runoff and erosion under varying rainfall and snowmelt; utilizing remote sensing to quantify rangeland vegetation and soil moisture over a range of watershed scales; understanding biodiversity of rangeland sites in diverse topography; predicting interactive effects of soil, plants, and climate on establishment of native grasses and shrubs after disturbance. Reynolds Creek Experimental Watershed is available to scientists and resource managers from private, university, state, and federal entities; cooperation in research and application of results is welcomed.

EVALUATING ECOLOGICAL CONDITION OF RIPARIAN ECOSYSTEMS USING AERIAL VIDEOGRAPHY

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ABSTRACT

Regular and thorough assessment of the ecological condition and trend of riparian ecosystems using ground-based methods is a difficult or impossible task given the cost, time, and personnel requirements involved. The Northwest Watershed Research Center is examining the potential of using aerial videography as a tool for remotely assessing ecological condition of riparian ecosystems. Aerial videography may provide land managers with an accurate and cost-effective means of identifying degraded sites in need of restoration and, more importantly, identifying sites in declining condition and in need of intensified management.

PAPERS PRESENTED WITHOUT A WRITTEN SUBMISSION

A Holistic View: The Spiritual Union of Man and Nature. ***Gerald B. Rouse***, Range Management Specialist, USDA Natural Resources Conservation Service, Spokane, Washington.

Riparian Land Management: Who Knows Best, Landowner or Public Agency? ***Pete Test***, Associate Director of Governmental Affairs, Oregon Farm Bureau, Salem, Oregon.

Human Pressures, Economic Development, and Environmental Quality: The River Not Taken. ***Lynn Huntsinger***, Department of Environmental Science, Policy, and Management, University of California, Berkeley.

Science, Policy, and Landscape Health in the Interior Northwest. ***James R. Karr***, Professor of Fisheries, Environmental Health, Civil Engineering, Public Affairs and Zoology, University of Washington, Seattle, Washington.

Lessons Learned: Interior Columbia Basin Ecosystem Management Program. ***Jeff Blackwood***, Forest Supervisor, Umatilla National Forest, Pendleton, Oregon.

Natural Disturbances and Human Perturbations that Shape the Biotic Structure of Riparian Ecosystems. ***J. Boone Kauffman***, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Historical Changes in Stream Habitats in the Columbia River Basin. ***Bruce A. Mcintosh***, Department of Forest Science, Oregon State University, Corvallis, Oregon, and ***James R. Sedell***, USDA Pacific Northwest Research Station, Corvallis, Oregon.

Riparian Dependence and the Ecology of Desert Trout Streams. ***Hiram Li***, ***Judith Li***, ***Christian Torgersen***, ***Todd Pearsons***, ***Cynthia Tait***, ***Joe Ebersole***, and ***William Liss***, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Chronic Disturbances and Regulatory Compliance: Critical Review of Use (and Abuse) of Forest Service Stream and Riparian Habitat Inventory Data from Blue Mountains National Forests 1991-1996. ***William J. Warren***, Contractor, Blue Mountains Native Forest Alliance, Baker City, Oregon and ***Richard L. Christian***, Graduate Student, Department of Animal Sciences, Oregon State University, Corvallis, Oregon.

Shading Effects on Stream Water Temperatures in the Grande Ronde Basin. ***Ken Diebel***, Union Soil and Water Conservation District, La Grande, Oregon and ***Mitch Wolgamott***, Oregon Department of Environmental Quality, La Grande, Oregon.

Understanding The Thermal Regime Of A Rangeland Stream: A Case Study. ***Tamzen K. Stringham***, ***John C. Buckhouse***, and ***William C. Krueger***, Department of Rangeland Resources, Oregon State University, Corvallis, Oregon.

The Use Of Riparian Vegetation Classifications For Survey And Management Of Riparian Ecosystems. ***Elizabeth Crowe***, Wetland/Riparian Ecologist, Malheur, Umatilla, and Wallowa-Whitman National Forests, Baker City, Oregon.

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