STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station **April 2006**

Wildland Fire in Ecosystems: Effects of Fire on Soil and Water

by Daniel G. Neary, Kevin C. Ryan, and Leonard F. DeBano

Fire is a natural disturbance that occurs in most terrestrial ecosystems. It is also a tool that has been used by humans to manage a wide range of natural ecosystems worldwide. As such, it can produce a spectrum of effects on soils, water, riparian biota, and wetland components of ecosystems. Fire scientists, land managers, and fire suppression personnel need to evaluate fire effects on these components, and balance the overall benefits and costs associated with the use of fire in ecosystem management. The publication, ***Wildland Fire in Ecosystems: Effects of Fire on Soil and Water***, has been written to provide up-to-date information on fire effects on ecosystem resources that can be used as a basis for planning and implementing fire management activities (figure 1). It is a companion publication to the recently published book, ***Fire's Effects on Ecosystems***, by DeBano and others (1998).

In the late 1970s, the USDA Forest Service published a series of state-of-knowledge papers about fire effects on vegetation, soils, water, wildlife, and other ecosystem resources. The papers, collectively called "The Rainbow Series" because of their covers, were widely used by natural resource managers. This publication updates both the Tiedemann and others (1979) paper on fire's effects on water and the Wells and others (1979) paper on soils.

The publication, ***Wildland Fire in Ecosystems: Effects of Fire on Soil and Water***, is divided into three major parts (A, B, C) and an introductory chapter that provides discussions of fire regimes, fire severity and intensity, and fire related disturbances. Part A describes the nature of the soil resource, its importance, characteristics and the responses of soils to fire and the relationship of these features to ecosystem functioning and sustainability. Part A is divided into three main chapters (2, 3, and 4) that describe specific fire effects on the physical, chemical, and biological properties of the soil, respectively.

Part B discusses the basic hydrologic processes that are affected by fire, including the hydrologic cycle, water quality, and aquatic biology. It also contains three chapters which

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The PRIMARY AIM *is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.*

CONTRIBUTIONS *are voluntary and will be accepted at any time. They should be typewritten, single-spaced, and limited to two pages. Graphics and tables are encouraged.*

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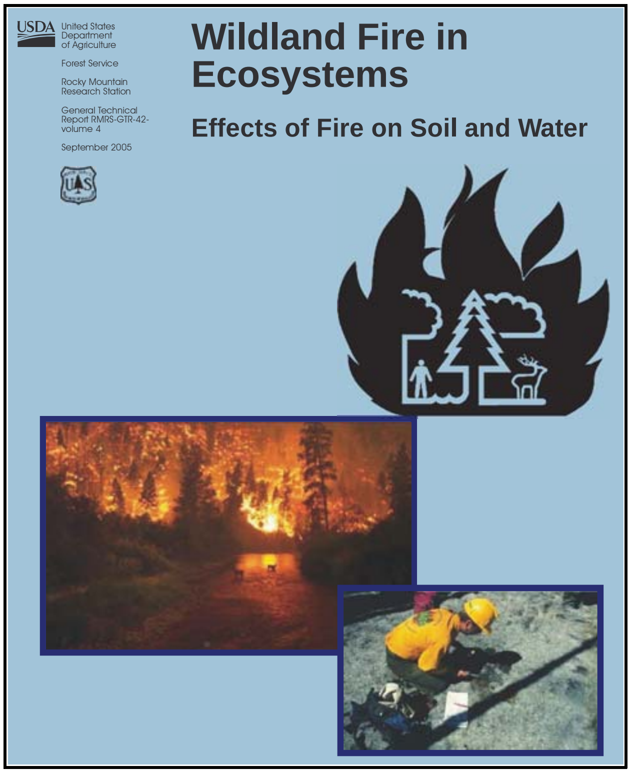

Figure 1. Cover page of ***Wildland Fire in Ecosystems: Effects of Fire on Soil and Water***. Left photo: Wildfire encroaching on a riparian area, Montana, 2002. Right photo: BAER team member, Norm Ambos, Tonto National Forest, testing for water repellency, Coon Creek Fire 2002, Sierra Ancha Experimental Forest, Arizona.

specifically discuss the effect of fire on the hydrologic cycle, water quality, and aquatic biology in chapters 5, 6, and 7, respectively.

Part C has five chapters that cover a wide range of related topics. Chapter 8 analyzes the effects of fire on the hydrology and nutrient cycling of wetland ecosystems along with management concerns. The use of models to describe heat transfer throughout the ecosystem and erosional response models to fire are discussed in chapter 9. Chapter 10 deals with important aspects of watershed rehabilitation and implementation of the Federal Burned Area Emergency Rehabilitation (BAER) program. Chapter 11 directs the fire specialists and managers to important information sources including data bases, Web sites, textbooks, journals, and other sources of fire effects information. A summary of the important highlights of the book are provide in chapter 12. Last, a glossary of fire terms is included in the appendix. The material provided in each chapter has been prepared by individuals having specific expertise in a particular subject.

This publication has been written as an information source text for personnel involved in fire suppression and management, planners, decision makers, land managers, public relations personnel, and technicians who routinely and occasionally are involved in fire suppression and using fire as a tool in ecosystem management. Because of widespread international interest in the previous and current "Rainbow Series" publications, the International System of Units (Systeme International d'Unites, SI), informally called the metric systems (centimeters, cubic meters, grams), is used along with English units throughout the volume. In some instances one or the other units are used exclusively where conversions would be awkward or space does not allow presentation of both units.

Hardcopies of ***Wildland Fire in Ecosystems: Effects of Fire on Soil and Water*** can be obtained by placing an order to Publications Distribution, Rocky Mountain Research Station, Fort Collins by telephone (970-498-1392), facsimile (970-498-1396), or e-mail (rschneider@fs.fed.us). An electronic copy of RMRS-GTR-42-volume 4 can also be downloaded online at http://www.fs.fed.us/rm/pubs/rmrs_gtr042_4.pdf.

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River Restoration in the Context of Natural Variability

by Ellen E. Wohl, Brian P. Bledsoe, David M. Merritt, and N. LeRoy Poff

What is river restoration?

People have manipulated rivers for thousands of years, and increasing population densities worldwide have been associated with increasing alteration of rivers throughout history. At any point in time and space, these alterations reflect societal expectations of river processes and form. Viewed in this context, contemporary river restoration and rehabilitation activities reflect the latest trend in societal expectations for natural, ecologically healthy rivers.

Various perceptions of what is meant by 'restoration' reflect the wide disparities in stakeholder interests, scientific knowledge, scales of interest, and system constraints encountered in practice. In the parlance of river management, 'restoration' describes activities ranging from "quick fixes" involving bank stabilization, fencing, or engineering fish habitat at the reach scale, to river-basin-scale manipulations of ecosystem processes and biota over decades. Because technical and social constraints often preclude 'full' restoration of river ecosystem structure and function, 'rehabilitation' is sometimes distinguished from restoration.

A key distinction between river restoration and other management actions is the intent to reestablish "natural" rates of certain ecological, chemical, and physical processes and/or to replace damaged or missing biotic elements. That is, restoration is often fundamentally about enhancing ecological integrity. We define ecological integrity as the ability to self-sustain desirable ecological entities (population, community, ecosystem) and processes (e.g., nutrient dynamics, sediment transport). Goals of individual restoration projects typically reflect this general theme, but details vary widely because the particular ecological entities and processes of interest differ greatly among projects and environmental settings. In many urban rivers, for example, the potential for ecological improvement is limited, and the principal benefits from a restoration project are social, such as building a sense of community by involving citizens as well as scientists and managers.

The current state of river restoration in the United States

Continuing degradation of river ecosystems and loss of aquatic biodiversity are widespread. River restoration is now accepted by government agencies and various stakeholders as an essential complement to conservation and natural resource management. The number of river restoration projects in the U.S. has increased exponentially in the last decade, and expenditures on small and mid-size projects alone average more than $1 billion a year. From a study of more than 38,000 restoration projects, Bernhardt and others (2005) found that the most commonly stated goals for river restoration in the U.S. are to enhance water quality, manage riparian zones, improve in-stream habitat, provide fish passage, and stabilize banks. However, despite legal mandates, massive expenditures, and the burgeoning industry of aquatic and riparian restoration, river ecosystems continue to deteriorate as a result of human influences. Furthermore, many restoration activities have failed. Recent reviews of river restoration projects across the country suggest some reasons for these failures (Bernhardt and others, 2005).

First, many projects designed to restore rivers are currently being conducted with minimal scientific context. Specifically, many projects lack (i) the inclusion of a solid conceptual model of river ecosystems; (ii) a clearly articulated understanding of ecosystem processes; (iii) recognition of the multiple, interacting temporal and spatial scales of river response; and (iv) long-term monitoring of success or failure in meeting project objectives following completion. These problems suggest that the scientific practice of river restoration requires an understanding of natural systems at or beyond our current knowledge, and presents a significant challenge to river scientists.

Second, most restoration projects focus on a single, isolated reach of river, yet many scientists advocate the watershed as the most appropriate spatial unit to use for most river restoration. Restoration undertaken within a watershed context reflects the importance of key processes and linkages beyond the channel reach , such as upstream/downstream connectivity, and hillslope, floodplain, and hyporheic/groundwater connectivity. The importance of these linkages is without question; water, sediment, organic matter, nutrients, and chemicals move from uplands, through tributaries, and across floodplains at varying rates and concentrations. Migratory fish move upstream and downstream during different stages in their life cycles. These obvious examples of the inextricable linkages within watersheds are too often ignored in river restoration. To date, restoration has largely been done on a piece-meal basis, with little to no monitoring to assess performance, and little integration with other projects. This reflects the lack of process-based approaches in current practice as well as the fact that comprehensive restoration strategies that reestablish watershed-scale connections and processes are more difficult to implement because of sociopolitical and financial constraints.

Third, restoration is too often focused on creating a desired form that is then artificially constrained. Because natural variability is an inherent feature of all river systems, restoration of an acceptable range of variability of process is more likely to succeed than restoration aimed at a fixed endpoint that precludes variability. Restoration of process is also more likely to address the causes of river ecosystem degradation, whereas restoration toward a fixed endpoint addresses only symptoms. The widespread clearing of the exotic riparian shrub tamarisk from western rivers has been supported by the public, politicians, and managers because tamarisk is perceived to be the cause of the problem rather than one of the many symptoms of altered rivers. Tamarisk removal has been sold as a means of restoring diversity of native communities and salvaging water through decreasing evapotranspiration, yet no scientific study has been able to quantify the yield on these investments.

To persist as healthy ecosystems, rivers must be able to adjust to and absorb change at the time scales over which change occurs. An ideal ecologically successful restoration creates hydrological, geomorphological, and ecological conditions that allow the targeted river to be self-sustainable in its new context. One of the implications of this understanding of river dynamics is that monitoring and evaluation of conditions before and after restoration must recognize the variability inherent even in “stable” rivers (figure 1). Restoration that focuses on process rather than form will more effectively address most restoration goals. Process is more crucial than form in goals such as a) improving water quality by changing infiltration-runoff paths and b) stabilizing banks and increasing pool volume by allowing riparian vegetation to remain along river banks. Restoration projects that attempt to create a static or fixed form, such as meanders with riprapped banks, commonly fail. Rivers possess physical integrity, an aspect of ecological integrity, when their processes and forms maintain active connections with each other in the present hydrologic regime.

Advancing the science and practice of river restoration

Rivers are highly valued by the public; everyone interacts with and pays attention to rivers. As the practice of river restoration continues to grow, the need to develop a sound scientific basis is obvious, as evidenced by the number of working groups and policy initiatives devoted to this topic within the federal government (e.g., USGS interagency River Science Network), non-governmental organizations (e.g., The Nature Conservancy, American Rivers, local watershed groups), and academia (e.g. the

National River Restoration Science Synthesis project (Palmer and others, 2003) and the National Center for Earth-Surface Dynamics).

Achieving restoration goals will be limited by a variety of scientific and non-scientific factors. Scientific limitations include unavailable information on critical ecosystem conditions or processes, and inadequate synthesis of available information during model development. Non-scientific limitations include infeasibility of certain desired restorative actions (e.g., eradication of exotic species, reintroduction of extinct native species), and philosophical differences among stakeholders and disagreements over who should bear the social and economic costs of restoration. Resolving resource-management issues across entire river basins and resolving conflicting interests among stakeholders requires degrees of coordination and cooperation rarely achieved in human society. However, as the public increasingly recognizes the link between ecological integrity and ecosystem goods or services such as clean water or productive fisheries, shifts in values may induce people to rethink assumptions about what is sociopolitically acceptable in restoration scenarios. For example, should reduced flood flows downstream from a dam constrain restoration efforts, or should restoration include greater flood-flow releases from the dam? Many factors assumed to be constraints twenty years ago are being re-examined as opportunities to restore rivers today. Rather than a dichotomy between pro-development and pro-environment, many scientists and practitioners are realizing that there is a middle

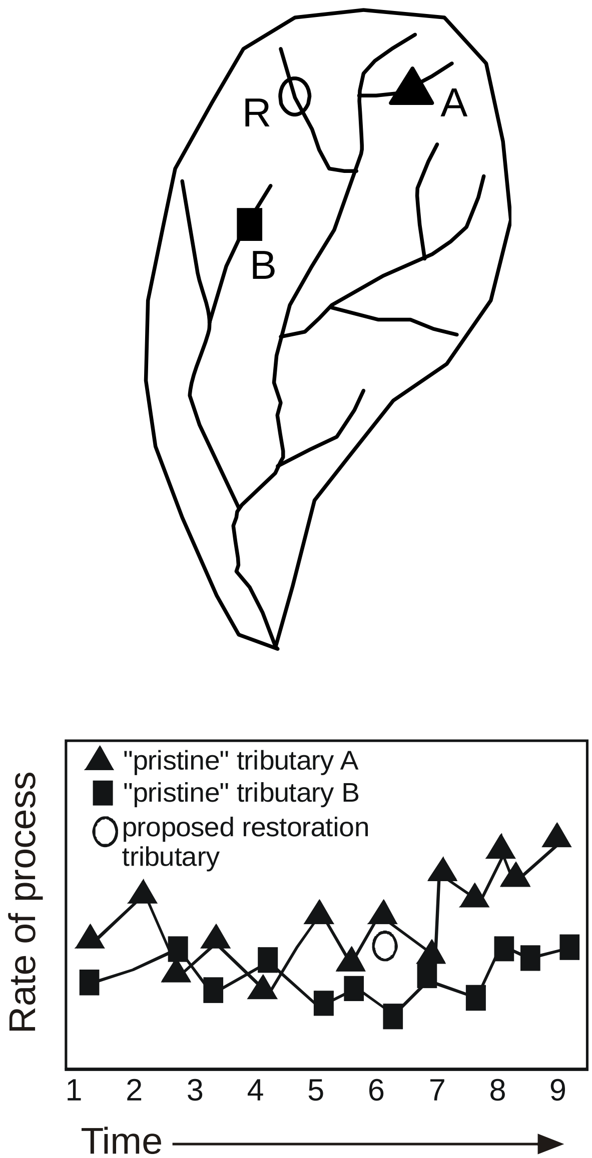

Figure 1. Schematic diagram illustrating that ecological and geomorphic processes in a stream vary naturally over time and space. Determining when a site is degraded sufficiently to warrant restoration requires an understanding of the range of natural variability. For simplicity, we assume that the process of interest has only been measured once in the proposed restoration tributary, but the “pristine” or reference tributaries are routinely monitored. The graph suggests that if only pristine tributary B had been sampled during times 1-6, one might conclude that tributary R was in need of restoration because the rates of some key process such as sediment flux or organic matter decomposition appear too high. However, with the addition of a second reference site (pristine tributary A), it appears that processes within tributary R are within the natural range of variability. Similarly, if sampling of reference sites continues over longer time periods (through time 9), this indicates that tributary R is well within the range of natural variability in the process being measured and restoration is not warranted.

ground in which some functions can be restored without great cost to water users.

River restoration can also be advanced by treating restoration projects as experiments that can teach us about ecosystem operation. Most restoration projects have been implemented without the study design, baseline data, and post-project appraisal needed to learn from them. Much of the published literature, which forms the basis of our ecological understanding, describes research conducted at space-time scales much smaller than those appropriate for restoration. Furthermore, many restorative actions are applied at scales too small to produce the intended effects on biotic populations and assemblages. A major limitation in advancing scientific knowledge to guide predictive restoration is the lack of opportunities to conduct large-scale experiments, where whole system responses can be evaluated at scales that match management actions. For example, restoration of flow regimes below existing water control structures presents tremendous opportunities to learn about system-specific responses that can guide future restoration actions. Experimental flood releases such as those on the Colorado River in Grand Canyon provide opportunities to pose and test hypotheses regarding the ecosystem effects of these floods. Despite the lack of standard experimental features such as randomization of controls and treatments, or replication, the flood releases create quasi-experiments that provide important knowledge about river response to restoration efforts.

Viewing restoration projects as experiments affords a framework for engaging scientific involvement early in the process and strengthens the rationale for monitoring the results of the restoration action. Adaptive management coupled with effective monitoring facilitates learning from experience, and has been repeatedly identified as a critical and missing component of existing river management programs such as that on the Platte River (National Research Council, 2005). We currently have far too few experiments at appropriate scales that are conducted adaptively and thus we have not yet developed scientific guidelines for how best to restore adaptively or over what time scale adaptive management should be applied.

We suggest that river restoration can be most effectively advanced with increasing emphasis on (i) implementing restoration within a clearly articulated scientific conceptual framework and a watershed context, (ii) restoring process rather than form, and (iii) monitoring and learning from ongoing restoration efforts. It is not unreasonable for society to expect a return on their investment in river restoration.

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Introduction to Suspended-Sediment Sampling: CD-Based Training and Reference

by John R. Gray

Suspended sediment can vary considerably in space and time. Reliable and accurate quantification of suspended-sediment fluxes require collection of water-sediment samples with calibrated instruments deployed by approved protocols. To this end, the CD-based training, ***Introduction to Suspended-Sediment Sampling***, describes the instruments and methods used by the U.S. Geological Survey (USGS) to obtain representative samples of suspended-sediment concentrations and particle-size distributions in streams (figure 1).

Although the course is narrated, the pace of the presentation is user-controlled. If the computer used to display the contents of the CD supports "MPEG" videos, students will be able to take advantage of videos interspersed in the presentation. The training should take 2 to 3 hours to complete. At the end of the presentation a test can be taken to assess how well the student understood the training material.

The presentation was developed using Macromedia Director MX 20041. The CD-ROM will run only on a Windows-based personal computer. Some of the internet links in the presentation are for internal USGS access only, hence, those using the CD without such access may not be able to realize the full benefits of the training.

This CD contains a subset of the information presented at the USGS's week-long field-based training course, "Sediment Data Collection Techniques" (course number SW1091; http://training.usgs.gov/ntc/courses/Course_Info/course_catalog.cfm?db_course_id=27). Students completing the CD-based training course may wish to subsequently enroll in the field-based course. The full suite of training courses offered by the USGS National Training Center, including other courses on sedimentology and geomorphology, can be found at: http://training.usgs.gov/ntc/courses/Course_Info/class_schedule.cfm.

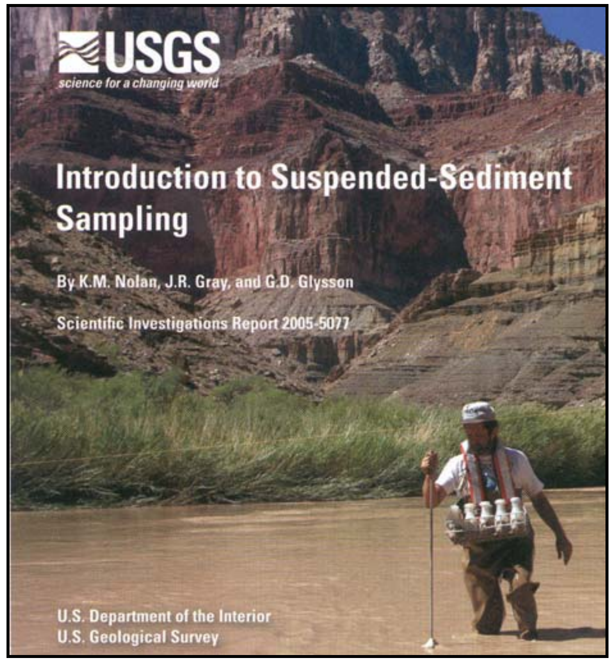

Figure 1. Cover design of the CD-based training, ***Introduction to Suspended-Sediment Sampling***.

Copies of the CD-based training, ***Introduction to Suspended-Sediment Sampling***, have been mailed to USDA Forest Service Supervisor Offices, Regional Offices, and Research Stations. Copies of the CD are also available upon request from STREAM by e-mailing your name and mailing address in label format to rmrs_stream@fs.fed.us. The product can also be downloaded online at: http://pubs.usgs.gov/sir/2005/5077/.

The citation for this CD-based training is: Nolan, K.M; Gray, J.R.; Glysson, G.D. 2005. Introduction to suspended-sediment sampling. U.S. Geological Survey Scientific Investigations Report 2005-5077.

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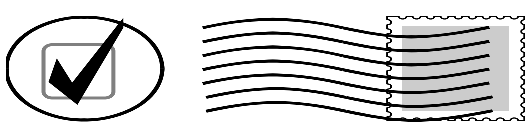

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