WESTERN WATERSHEDS

SCIENCE • SENSE • STRATEGIES

**PROCEEDINGS OF THE SEVENTH BIENNIAL
WATERSHED MANAGEMENT COUNCIL CONFERENCE**

Watershed Management Council

October 19-23, 1998 Boise, Idaho

**CENTERS FOR
WATER AND
WILDLAND
RESOURCES**

**WATER RESOURCES CENTER REPORT NO. 98
ISBN 1-887192-10-7
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Sponsored by the

WATERSHED
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Edited by
Charles W. Slaughter

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OVERVIEW, SEVENTH ANNUAL WATERSHED MANAGEMENT CONFERENCE PROCEEDINGS

Understanding, living in and utilizing our western watersheds in a long-term, sustainable manner is predicated on fundamental knowledge gained thorough "good science," on having the good sense to process that knowledge, and on the development of strategies to apply that improved understanding to management practices and decisions. The Seventh Annual Watershed Management Conference included elements of all these components of watershed management.

Scientists, educators, lay public, field personnel and decision makers gathered in Boise, Idaho, to share their scientific knowledge, experience, individual perspectives and diverse opinions. **"Science"** in watersheds and their management was a theme throughout the conference, beginning with Tom Dunne's keynote address and extending from basic physical processes to TMDLs, forest roads and cooperative management actions. **"Sense"** was evident in application of science to these issues, highlighted by Walt Megahan's keynote address and evidenced in presentations and discussions on hydrologic processes, restoration and decision making. **"Strategies"** were presented in fire rehabilitation, urban river and floodplain management, collaborative watershed partnerships, and in development of national agency policy for specific issues such as roads.

Science was further stressed in Short Courses on *Eco-Hydraulics and Physical Processes in Watershed Management*, and *Geographic Information Systems*. **Sense** and **Strategies** were further elaborated in field trips to the Boise Front and Reynolds Creek Experimental Watershed. The extensive poster session (our largest in a WMC conference to date) allowed exploration of many additional facets watershed management in the west.

The decision by the Watershed Management Council to offer this Seventh Annual Watershed Management Conference in Idaho, in the interior Pacific Northwest, was not taken lightly. The success of the conference confirms the widening interest in rational, sustainable watershed management across the entire suite of western environments and landscapes. From the Sierra Nevada to the Oregon Coast, from the Owyhees of southwestern Idaho to the Olympic Peninsula of Washington, watershed management is a common concern, a common need, and a unifying concept in our region. Full participation of all conference attendees, speakers and sponsors was crucial to the success of this conference, and remains essential to the Watershed Management Council goals of advancing the art and science of watershed management.

Charles W. Slaughter
Conference Chair

ACKNOWLEDGMENTS

The Watershed Management Council is very glad to continue our 12 year tradition of biennial watershed management conferences with this event in the Boise River watershed. I remember attending the original conference in 1986 in Sacramento, California, where the organizers expected perhaps 100 attendees and over 300 showed up for this “new” theme of watershed management. Trying to capture the excitement and momentum of the event, the Watershed Management Council was born. It has the express mission of “promoting the advancement of the art and science of watershed management.” which was also the purpose of this 7th Biennial Conference.

Despite its origins in California, the Council’s membership and interests have been expanding into other western states for years. When Chuck Slaughter came on as a member of WMC’s Board in 1997, we gave him as his first task - even before he had warmed his seat - the job of organizing this 7th Biennial Conference. Chuck was in an ideal role, we felt, to help link the interior and coastal western states with his position and location in Boise. He is Research Leader of the Northwest Watershed Research Center and Reynolds Creek Experimental Watershed with USDA’s Agricultural Research Service, and also holds adjunct faculty appointments with the University of Idaho and Utah State University. Dr. Slaughter deserves a great deal of thanks for organizing this ambitious week-long gathering of watershed afficionados in Boise, as well as for obtaining the great conference facility at MK Plaza. Besides being Conference Chair, he also served a Facilities Coordinator and Editor of this Proceedings — and certainly has more energy (and patience) than I have.

Assisting Chuck were many devoted people who also deserve much praise. A Boise group met several times to help identify session topics and speakers. Peter Goodwin (Univ. of Idaho) and Jim McNamara (Boise State Univ.) organized Monday’s Short Courses. Serving as Plenary Session Moderators were Mark Hardy (USGS), Sari Sommarstrom (WMC), Bill Clayton (Boise River 2000), Jim Clayton (USFS), Terry Kaplan-Henry (WMC), and John Fend (BLM). Workshop Coordinator was Polly Hays (WMC) and Poster Session Coordinator was Jim Bergman (WMC). Registration was handled in Boise by Rick Kattelmann, as well as by Terry and Jim, of the WMC Board. All of the speakers contributed greatly to the success. We are also thankful for our contributing co-sponsors who helped make the event more affordable for all.

In summary, this watershed event attracted 180 people from 11 states and many organizations. Evaluations generally rated the short course, plenary session, and workshops as good to excellent. We were able to socialize and celebrate at the Basque Center one evening and reward Clay Brandow, Past-Past-Past President of WMC, with a recognition plaque for services above and beyond the call of duty. Sometimes we need to look back in order to look forward. We’ve come a long ways, and plan to continue contributing to the progress of watershed management for many more years.

Sari Sommarstrom, *President 1998-2000*
Watershed Management Council

KEYNOTE ADDRESS

UNDERSTANDING PHYSICAL PROCESSES IN WATERSHED MANAGEMENT[1]

Tom Dunne[2]

Abstract. *Watershed management involves making decisions, promoting and taking action to conserve or alter the condition of watersheds and/or their effluents. For watershed management to be effective, goals or emphasis areas need to vary as a function of environments. Understanding of the physical processes in watershed management requires hydrologic studies which require understanding physical, chemical, and biogeochemical mechanisms. Studies should focus on current and future land management issues located in watersheds from which results can be obtained. Water and land management agencies would provide expertise for these studies. Conclusions about watershed management need to be science based using measurement and data analysis, professional judgement and the assessment of new ideas. This is often high profile, emotionally charged, commercially significant and litigious. The following actions are needed to provide the next generation of research useful for watershed management: review the questions; review the nature of the answers; expand potential field areas; diversify recruitment of hydrologists; improve communication; support expansion techniques; improve transferability of techniques and results; and model the use of hydrologic results in specific adaptive management programs.*

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[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*
[2]*University of California, Santa Barbara, California 93106*

PLENARY SESSION PAPERS

Plenary Session

TMDLS: REGULATORY NIGHTMARE OR TOOL FOR UNDERSTANDING OUR WATERSHEDS?

Organizer: *Mark Hardy,*
U.S. Geological Survey
Boise, Idaho

THE EVOLVING NATURE OF TMDLS[1]

Leigh Woodruff[2]

Abstract. *Section 303(d) of the Clean Water Act, adopted in 1972, requires states to 1) identify waters which are not meeting water quality standards, and 2) establish total maximum daily loads (TMDLs) for these waters. A TMDL is a written quantitative assessment of water quality problems which establishes pollutant reductions needed to achieve water quality standards, and allocates pollutant load reductions amongst pollutant sources. Court driven TMDL development schedules have brought a sharp focus to the practical difficulties of TMDL development, and shortcomings of existing regulations. EPA and states have little experience developing nonpoint source TMDLs for the most common causes of impairments in the West; sediment and temperature. Technical analysis tools are not well developed, usually time consuming, and typically must be tailored to fit each watershed.*

Recognizing the extreme complexity of the 303(d) task, EPA solicited direction from a Federal Advisory Committee (FACA). Program areas FACA recommended changing include listing of impaired waterbodies, TMDL development, TMDL implementation, and waters impaired by extremely difficult problems. EPA has begun a process to revise the 303(d) regulations and guidance, and is carefully considering the FACA recommendations. Tentative plans are to propose draft regulations by Spring 1999.

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[1]Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 97, University of California, Davis (1999).
[2]U.S. Environmental Protection Agency, 1435 N. Orchard Boise, Idaho 83706, woodruff.leigh@epamail.epa.gov

INVESTIGATIONS OF WATER QUALITY IN THE TUALATIN RIVER BASIN, OREGON, AND THEIR ROLE IN THE TMDL PROCESS[1]

Stewart A. Rounds[2]

Abstract. *The U.S. Geological Survey (USGS) has studied eutrophication processes in the Tualatin River, Oregon, for most of the past decade. Prior to 1988, high concentrations of ammonia (> 20 mg/L) and phosphorus (> 2 mg/L) were discharged to the river from two large wastewater treatment plants (WWTPs) operated by the Unified Sewerage Agency (USA). These loads of ammonia and phosphorus led to low dissolved oxygen concentrations and large phytoplankton blooms in the river during the warm, low-flow months between May and October. In response, Total Maximum Daily Loads (TMDLs) of ammonia nitrogen and total phosphorus were set in 1988. In 1990, after upgrades to the WWTPs were under way, the USGS and USA initiated an investigation of water quality in the Tualatin River. This investigation quantified the sources and sinks of water, nitrogen, and phosphorus in the main stem of the river. An important natural and previously unknown ground water source of phosphorus was discovered. Photosynthetic production was determined to be the largest instream source of dissolved oxygen, while sediment oxygen demand was the most important sink. A model of the lower main stem Tualatin River that simulates flow, temperature, nutrients, phytoplankton, and dissolved oxygen was constructed and used to provide insight for future river management. These results and model simulations are being used in an ongoing reassessment of Tualatin River TMDLs by the Oregon Department of Environmental Quality.*

INTRODUCTION

The Tualatin River Basin, a 712 square mile watershed on the west side of the Portland, Oregon, metropolitan area, is home to a growing population of more than 380,000 people. The population depends on the Tualatin River as a source of drinking water and irrigation water, a place to recreate, and as habitat for fish and other wildlife.

From its source in the forested Coast Range mountains, the Tualatin River (figure 1) flows into and meanders through a valley bottom that is intensively farmed. It skirts the edge of several urban areas, then widens to about 150 feet and slows as it enters a reservoir reach about 30 miles upstream from its mouth [river mile (RM) 30]. This reservoir reach meanders for more than 25 miles until the river reaches a low- head dam at RM 3.4. The river passes through several urban centers before discharging to the Willamette River at West Linn, Oregon.

As was the case with many rivers throughout the United States several decades ago, the quality of the Tualatin River degraded over time because of water withdrawals, loss of wetlands, introduction of wastestreams, and pollution in general. Water quality in the river started to improve with the creation of the Unified Sewerage Agency (USA) in the early 1970s, which was charged with managing urban wastewater and stormwater. Despite the advances, however, the river still produced violations of the State of Oregon minimum dissolved oxygen (DO) standard, maximum pH standard, and chlorophyll-a action level during the low-flow summer periods of the mid-1980s (Oregon Department of Environmental Quality, 1997). The river was listed as water-quality limited by the Oregon Department of Environmental Quality (ODEQ), and Total Maximum Daily Loads (TMDLs) were set for ammonia and total phosphorus in the river in 1988.

Tualatin River TMDLs

When the TMDLs were set, the urban population was served by four wastewater treatment plants (WWTPs); two of the WWTPs were fairly large and discharged to the river year-round, while the two smaller plants only discharged to the river during the high-flow winter period. Ammonia loads from the WWTPs were large enough in the 1980s to threaten DO levels and, possibly, be toxic to fish. At the same time, large algal blooms frequently caused violations of the pH standard and caused DO concentrations to fluctuate greatly, often contributing to violations of the minimum DO standard. The algal blooms impaired the aesthetic quality of the river.

A TMDL was set for ammonia to protect the minimum DO levels in the river and to protect the fish from ammonia toxicity. Another TMDL was set for total phosphorus in an attempt to restrict the growth of algae in the river, thus preventing pH violations and restoring the aesthetic quality of the river (Oregon Department of Environmental Quality, 1997).

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999)*
[2]*U.S. Geological Survey, 10615 SE Cherry Blossom Drive Portland, OR 97216, sarounds@usgs.gov*

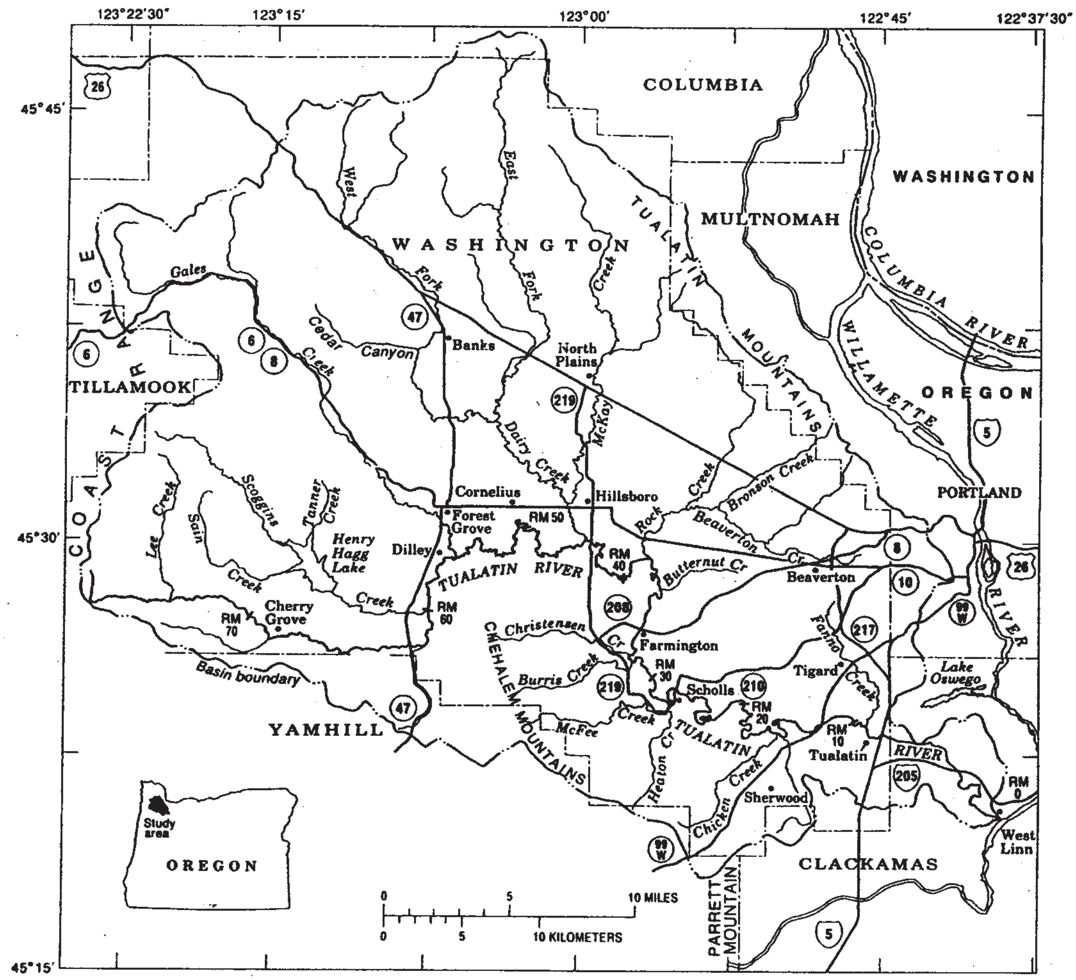

Figure 1. Map of the Tualatin River basin [RM, river mile]

The USGS Role In The Tualatin River Basin

In 1989, U.S. Congressional Representative Les AuCoin requested USGS assistance with technical water-quality issues in the Tualatin River as they related to the TMDL provision of the Clean Water Act. The USGS, in partnership with USA, began a study of water quality in the Tualatin River in 1990. The objectives of that investigation were:

> To identify and characterize the sources of nutrients (nitrogen and phosphorus) to the main stem Tualatin River,
>
> To quantify those processes that produce and consume DO in the Tualatin River, and
>
> To construct a process-oriented model of flow and water quality for the Tualatin River, and use it to better understand the dynamics of water quality and provide insight for river management.

The focus of this work was on the low-flow summer period, defined here as May 1 through October 31, because that was the period when most of the problems related to DO, pH, and algae occurred. This paper provides an overview of the results of the USGS study, and shows how those results have assisted river managers and State regulators as they continue to struggle with TMDL issues for the Tualatin River.

SOURCES OF WATER AND PHOSPHORUS

In the mid-1980s, when the original Tualatin River TMDLs were set, the WWTPs typically were the largest sources of ammonia and phosphorus to the river. Upgrades for advanced nutrient removal in the WWTPs, however, were already in progress to reduce effluent ammonia loads. By the time state-of-the-art phosphorus removal was added to the WWTPs in the 1990-1991 period, the distribution of ammonia and phosphorus sources to the river had been altered markedly from its pre-TMDL status. One of the first tasks of the USGS study, therefore, was to identify the post-TMDL sources of nitrogen and phosphorus to the main stem Tualatin River and determine their relative distribution.

Sources of Water

Before characterizing the sources of nutrients to the river, the sources of water to the river had to be determined. A survey of all the sources and sinks of water to the river reach between RM 51.5 and 16.2 was carried out in June and July of 1992. This reach was chosen because a preliminary analysis of the available streamflow data indicated the possible presence of an important, yet unidentified, source of water to this reach. During this survey, USGS personnel travelled the entire length of the reach and measured the rate of every identifiable inflow, from large tributaries such as Dairy and Rock Creeks and the Rock Creek WWTP, to small inflows such as tile drains, small ungaged tributaries, and visible ground water seeps. Withdrawal rates from irrigation pumps were estimated using water rights data and a known relation between irrigation water use and meteorological conditions.

The results of the source survey are shown in figure 2A, where the entire pie represents all of the sources of water to the river in the RM 51.5 to 16.2 reach (all sources = river discharge at RM 16.2 plus all withdrawals from that reach). Clearly, the water entering the reach at RM 51.5 (upstream inflow) is the largest single source. The Rock Creek WWTP is the next largest source of water to the reach, followed by Dairy and Rock Creeks. Even accounting for sources of water from tile drains and small wetland sources (Jackson Bottom), an unidentified source must be present to account for 6.0 percent, or roughly 10 ft3/s (cubic feet per second), of the water entering this reach. This unknown source probably comprises mainly ground water discharge, as well as any other tile drains, seeps, or tiny tributaries that may have been missed by the survey.

Sources of Phosphorus

During the source survey, water samples also were collected for every identifiable source of water to the RM 51.5 to 16.2 reach. These samples were analyzed for their phosphorus content (Doyle and Caldwell, 1996), and loads of phosphorus from each source were determined. Loads removed by irrigation withdrawals were similarly estimated. The results of the phosphorus source survey are shown in figure 2B. The entire pie represents all of the sources of phosphorus to the RM 51.5 to 16.2 reach. Although total phosphorus is not a conservative species, it is assumed that total phosphorus was near-conservative in this reach because those processes that consume or produce it were expected to be insignificant in this reach of the river. Uptake by algae and subsequent settling, for example, was not considered to be important because this reach had a very small algal population. Similarly, release of phosphorus from the sediments was considered to be insignificant because such releases normally occur only adjacent to anoxic water columns, and anoxia did not occur in this reach.

The distribution of phosphorus sources has a much different pattern when compared to that for water. The upstream inflow, the largest source of water to the reach, also is the largest source of phosphorus, but its contribution to the total source load is much smaller because of the relatively low phosphorus concentrations in the upstream inflow water. Dairy Creek is a significant contributor of phosphorus, as is Rock Creek. The contribution of

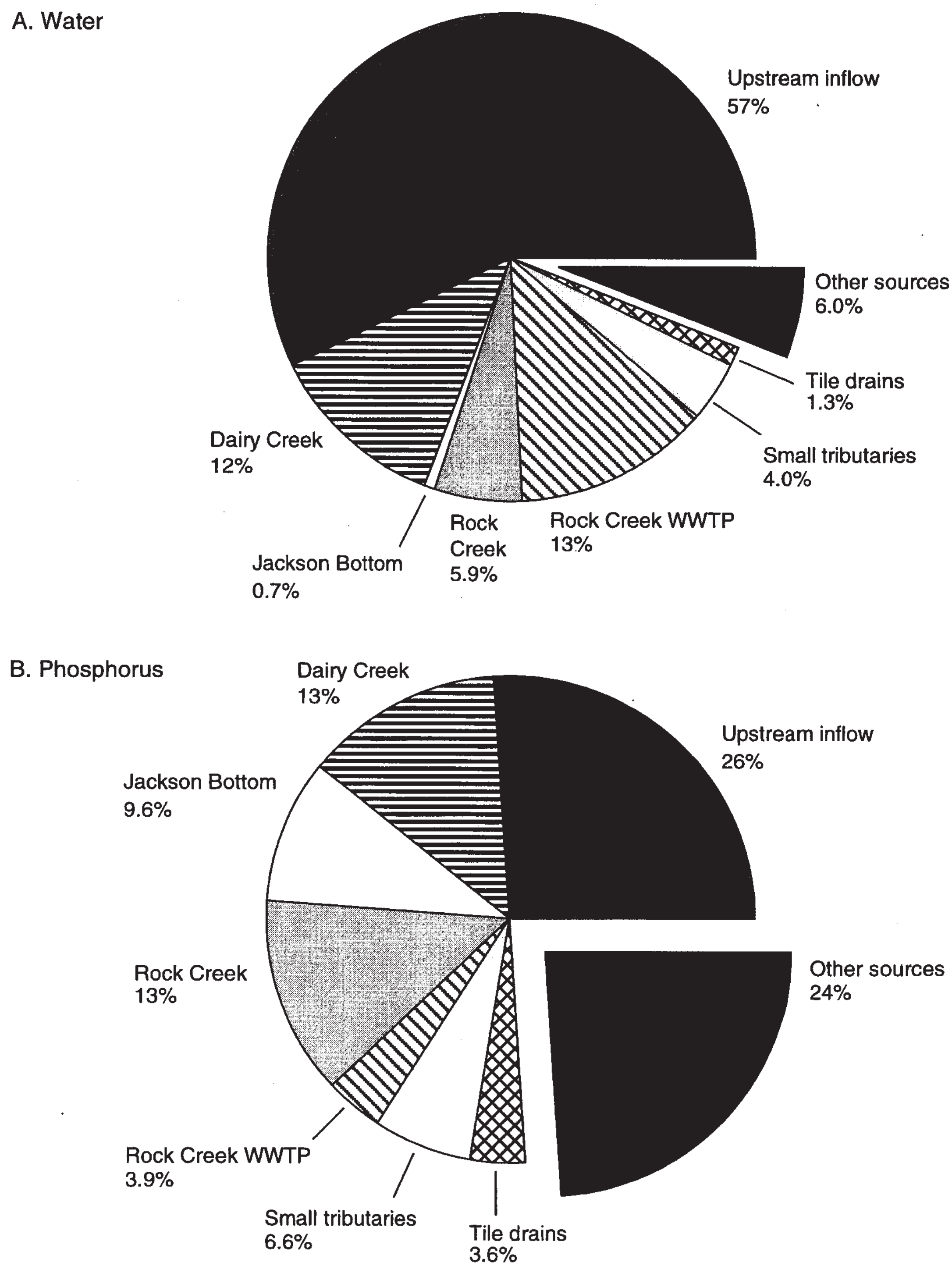

Figure 2. Sources (a) water and (B) total phosphorus to the river mile 51.5 to 16.2 reach of the main stem Tualatin River during the 1992 low-flow summer season. Individual percentages may not add to 100 due to round-off errors. [WWTP, wastewater treatment plant]

the latter to the total phosphorus load, however, is greater than its fractional contribution of water because Rock Creek has relatively high phosphorus concentrations. The Rock Creek WWTP, a significant source of water to the reach, is only a small source of phosphorus after treatment. The Jackson Bottom wetland contributed a significant phosphorus load at the time of this survey, despite contributing a very small amount of water. By far the most interesting contribution, 24 percent, belongs to an unmeasured source. In order to contribute this much phosphorus from an inflow of only 10 ft3/s (6 percent, figure 2A), the phosphorus concentration in this source or mixture of sources must average more than 0.4 mg/L, a concentration higher than that found in most of the other source waters.

As a result of this finding, the USGS initiated a detailed investigation of ground water flow and quality throughout the Tualatin River Basin to identify the potential for ground water to contribute significant phosphorus loads to the river. A regional ground water survey was performed on domestic wells throughout the basin. In addition, piezometers were installed at a number of locations in the middle of the river channel to obtain samples of ground water just before it discharged into the river. Indeed, static head levels in all of the piezometers indicated that the ground water was moving upward into the river. To verify the ground water discharge, seepage meters were installed near the piezometers; positive seepage into the river was measured at all sites. The phosphorus concentrations in the ground water were much higher than those found in many of the other source waters (figure 3), and higher than the 0.4 mg/L necessary to account for the missing phosphorus load to the RM 51.5-16.2 reach.

Additional work by the USGS and by researchers from the Oregon Graduate Institute and Portland State University (Wilson, 1997) showed that high concentrations of phosphorus are present in ground water throughout the unconsolidated sediments of the Tualatin River Basin, and that the elevated concentrations are likely of natural origin. The high concentration of phosphorus in the regional ground water creates a significant background load of phosphorus to the river, a much larger background load than expected when the original phosphorus TMDL was set. This natural background load of phosphorus will complicate efforts to reduce total phosphorus concentrations in the river to their TMDL-required levels. Indeed, these natural loads may prevent the attainment of the present total phosphorus TMDL.

SOURCES AND SINKS OF DISSOLVED OXYGEN

One of the most important objectives of the USGS investigation was to measure the rates of production and consumption of DO in the Tualatin River. Experiments were conducted and data were collected, therefore, to determine the rates of algal primary productivity, carbonaceous biochemical oxygen demand (CBOD), ammonia nitrification, and sediment oxygen demand (SOD). Many other rate parameters that affect important river processes also were measured, such as the algal settling rate, the Michaelis-Menten half-saturation constants for nitrogen and phosphorus utilization by algae, light saturation parameters for the algal population, and light extinction coefficients, to name a few.

The rates measurements allowed gross comparisons to be made regarding the relative importance of each of the sinks of DO. One of the most interesting results was that the SOD was a more important sink than expected, and that it was far less spatially variable than once assumed. It had been widely assumed by many scientists and regulators that the Tualatin River SOD was caused largely by the decomposition of dead algal detritus that had settled to the bottom of the river. It was thought, therefore, that reducing the size of the algal blooms would decrease the SOD significantly and enhance the river's DO. If the SOD were caused primarily by dead algal detritus, then one would expect the rate of SOD to be highest in the lower part of the reservoir reach of the river, where the large phytoplankton populations occur. Similarly, the SOD should be low in those reaches of the river upstream of significant algal activity. The data showed otherwise. Measurements of temperature-corrected SOD showed it to be remarkably independent of the zone of algal activity. The rate of SOD, rather than being driven by an algal source of organic matter, is probably caused by a terrestrial source of organic material (Rounds and Doyle, 1997).

THE TUALATIN RIVER MODEL

A model of flow, temperature, and water quality was constructed for the Tualatin River, starting at RM 38.4, just upstream of Rock Creek and the Rock Creek WWTP (RM 38.1), and covering the entire reservoir reach to the low-head dam at RM 3.4 (figure 1). A U.S. Army Corps of Engineers reservoir model called CE-QUAL-W2 (Cole and Buchak, 1995) was used for this application, with some modifications as documented by Rounds and others (1998). In addition to flow and water temperature, the model includes all of the most important processes and constituents that affect DO in the Tualatin River. Simulated water-quality constituents include chloride, suspended solids, dissolved solids, ammonia, nitrate, dissolved orthophosphate, dissolved organic matter, detritus, phytoplankton, zooplankton, DO, and sedimentary organic matter. Calibrated to an 18-month period from May through October of 1991 through 1993, the model performed very well. It captured the dynamics of the most important water-quality processes in the Tualatin River and simulated the nutrient, DO, and phytoplankton concentrations with acceptable accuracy (Rounds and others, 1998).

Stewart A. Rounds

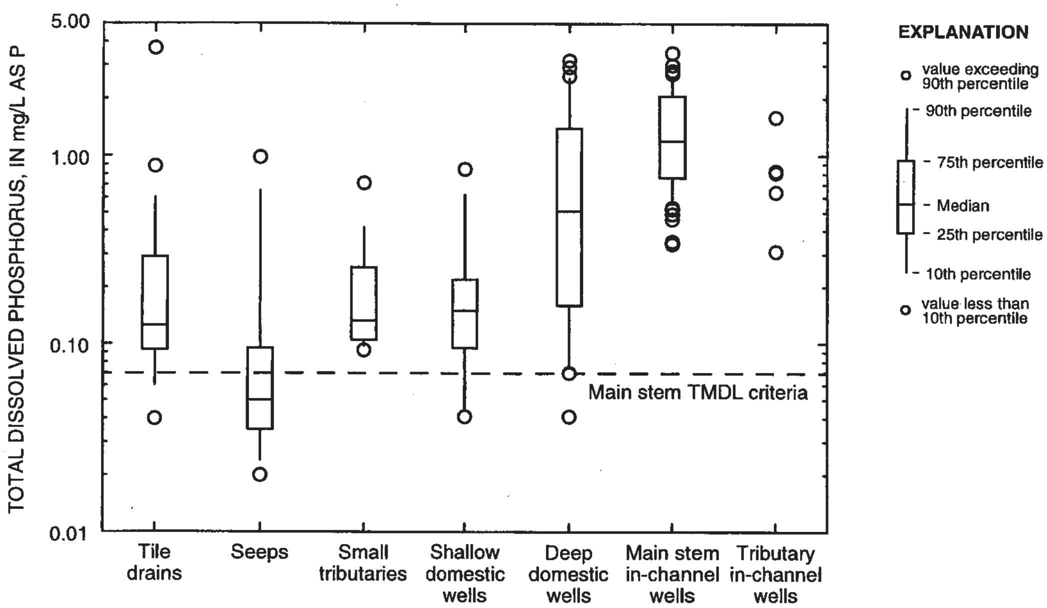

Figure 3. Total dissolved phosphorus concentrations observed in several potential source waters to the Tualatin River. [mg/L, milligram per liter: TMDL. Total Maximum Daily Load]

The USGS Tualatin River model was used for a number of diagnostic purposes, such as quantifying the sources of nitrogen and phosphorus to the model reach, identifying unknown sources or sinks of water, nitrogen, phosphorus, and DO, comparing the relative magnitude of point and nonpoint sources, assessing the relative importance of sources and sinks of DO, and assessing the role of phytoplankton in the DO budget. In addition, the model was used to estimate the effects of hypothetical changes in river characteristics or river management on water quality. In this way, the effects of increased flow augmentation, modifications to the dam at RM 3.4, reductions in phosphorus loading, changes in point- source ammonia loads, reduced stream temperature, and population growth, to name a few, were simulated with the model (Risley, 1997; Rounds and others, 1998; Rounds and Wood, 1998; Wood and Rounds, 1998).

The next two sections illustrate how the Tualatin River model was used to better understand the processes affecting DO, and to provide information used in the reassessment of the ammonia TMDL.

Sources and Sinks of DO During an Algal Bloom

By customizing the output of the computer model, all of the simulated sources and sinks of DO can be quantified and compared. This technique was used in the USGS study to quantify the relative importance of each component of the DO budget during different parts of the low-flow summer period. This sort of analysis can be taken one step further through more customization of the model to track the sources and sinks of DO to a particular parcel of water as it moves through the model grid. Water is added or removed from the parcel as that parcel passes point-source inputs or withdrawals; DO in the parcel is produced or consumed according to the biological and chemical reactions occurring within it.

The results of this type of tracking technique are illustrated in figure 4. In this example, a hypothetical parcel of water was released at the upstream end of the model grid (RM 38.4) on June 29, 1991, and followed downstream to the end of the model grid (RM 3.4), where it exited the system. Figure 4 shows the arrival time of the water parcel at particular stations in the model grid; the total travel time through the 35 mile reach was approximately 7.8 days. More important than the travel time, however, is the simulated loss or gain of DO from station to station due to each component of the DO budget (figure 4). The period of time of the simulation (early July of 1991) was characterized by conditions favorable for a bloom of phytoplankton: warm water, a sufficiently long residence time, ample nutrients, and plenty of sunshine. As the phytoplankton population in the water parcel grows, the net effect of photosynthesis (production minus respiration) becomes the largest single influence on the water parcel's DO, especially in the reaches of the model grid downstream of RM 16.2. In this example, the transfer of oxygen across the air/water interface (reaeration) changes from a source to a sink for DO as the parcel moves downstream, illustrating that the photosynthetic production of oxygen causes the DO to exceed its solubility somewhere downstream of RM 16.2. SOD is spatially a consistent sink for DO; its influence increases slightly as the parcel moves downstream, mainly due to an increase in water temperature and an increase in stream width. CBOD also is an important sink for DO in this example, especially in the lower part of the reservoir reach because of the decomposition of organic matter excreted by the phytoplankton. Throughout this reach, however, production more than compensates for consumption, resulting in a net positive change in the DO concentration.

Modeling techniques such as this were instrumental in assessing the relative importance of each of the various sources and sinks of DO in the Tualatin River during the low-flow summer period. The relative importance of each process changes over the summer season, of course, depending on physical conditions such as river flow and water temperature, and biological conditions such as the status of the algal population (in bloom, in decline, or absent), to name a few. Over the entire course of the summer, however, the most important source of DO was photosynthetic production, and the most important sink was SOD (Rounds and others, 1998).

Ammonia Loads and the Point Two Rule

In addition to providing a better understanding of observed conditions, the Tualatin River model was used to explore the effects of hypothetical conditions superimposed on the observed calibrated conditions. In this way, the model was used to provide insight into the potential changes in water quality that might result from changes in river management. One example that is particularly relevant to TMDLs is the use of the model to assess the ammonia assimilative capacity of the Tualatin River (Rounds and Wood, 1998).

The ammonia assimilative capacity is defined as the load of ammonia that can be carried by the river without causing violations of the DO standard. Ammonia loads can be detrimental to DO levels because certain species of bacteria can convert ammonia to nitrate in the river; this nitrification process consumes DO. In the Tualatin River, the largest sources of ammonia to the river normally are the WWTPs. The model was run with constant loads of ammonia [0 to 1500 lb/d (pounds per day)] set for the two WWTP sources, superimposed on the observed hydrologic and climatic conditions of the 18-month calibration period. The total inorganic nitrogen load from the WWTPs was unchanged from that of the calibration to minimize any effect on the algal population. The result

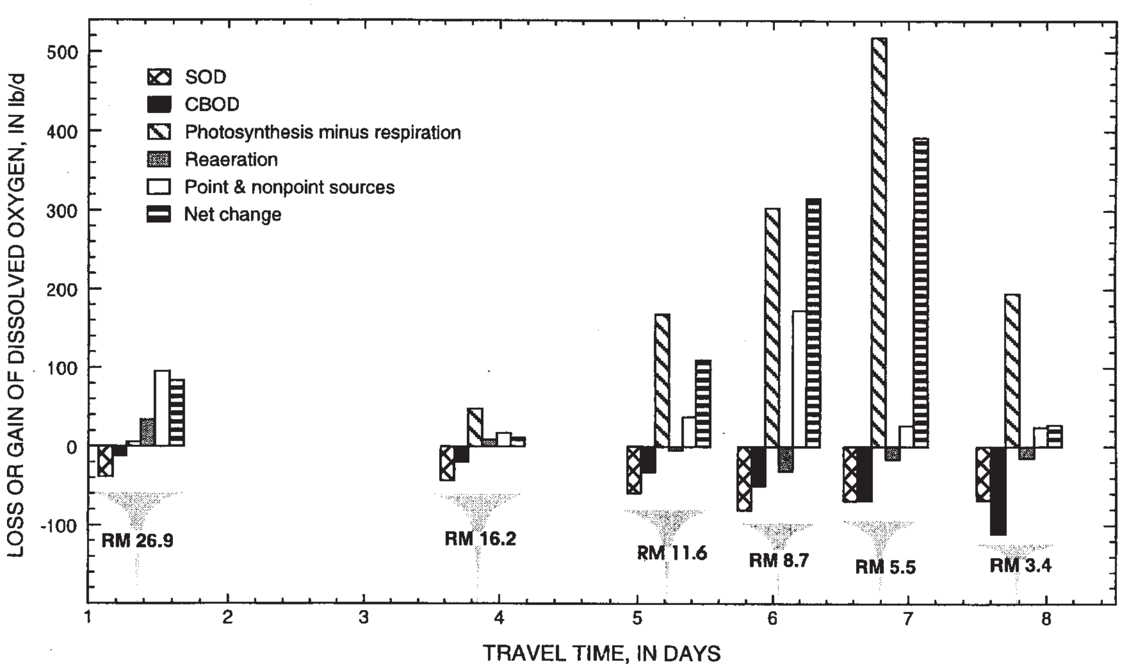

Figure 4. Simulated loss or gain of dissolved oxygen through several reaches of the Tualatin River from RM 38.4 to 3.4 for a hypothetical parcel of water released under conditions favorable for an algal bloom. A negative reaeration represents a loss supersaturated dissolved oxygen [lb/d, pound per day; RM, river mile; SOD, sediment oxygen demand; CBOD, carbonaceous biochemical oxygen demand]

Stewart A. Rounds

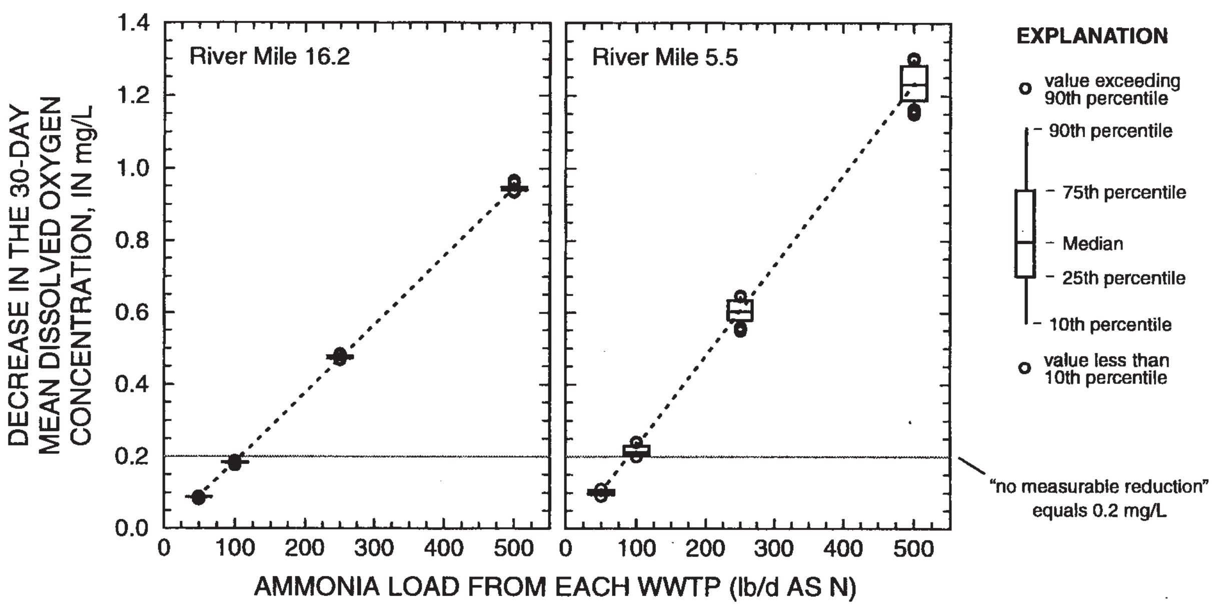

Figure 5. Simulated dissolved oxygen consumption due to ammonia nitrification as a function of the WWTP ammonia load. These plots include only conditions in the 18-month model calibration period when the 30-day mean dissolved oxygen standard was violated in the absence of WWTP ammonia loads. [mg/L, milligram per liter; lb/d pound per day; WWTP. wastewater treatment plant]

from these simulations was that the ammonia assimilative capacity of the river changes as a function of river flow, water temperature, and photosynthetic activity. Some combinations of conditions exist such as the high-flow, cold water, and short residence time conditions often encountered in May where the river can assimilate more than 1,500 lb/d of ammonia nitrogen from each WWTP without causing a violation of the DO standard. At other times such as the low flow, warm water, long residence time, and low photosynthetic activity conditions often encountered in October the ammonia assimilative capacity of the river is zero.

Tualatin River managers and regulators now recognize that the original TMDL for ammonia in the Tualatin River was set too high to adequately protect the river's DO (Rounds and Wood, 1998). These simulations of ammonia assimilative capacity will aid ODEQ personnel as they revise that TMDL. Under conditions when the river already is violating the DO standard in the absence of point-source ammonia loads, the ODEQ still allows a point-source discharge of ammonia, as long as it results in no measurable reduction in the 30-day mean (or the 7-day mean of daily minimum) DO concentration. ODEQ defines no measurable reduction in this case as 0.2 mg/L of DO (Oregon Department of Environmental Quality, 1997). The model simulations were analyzed for periods when a violation of the DO standard occurred in the absence of point-source ammonia loads. Once those conditions were isolated, the DO loss caused by additional loads of ammonia from the WWTPs was calculated. Figure 5 shows the result, which indicates that a load of approximately 100 lb/d of ammonia nitrogen from each WWTP will cause a 0.2 mg/L reduction in the 30-day mean DO concentration.

The Tualatin River model, used in this manner, helped to define an acceptable point-source ammonia load under worst-case river conditions. ODEQ and river management agencies such as USA can use this information to develop a new ammonia TMDL for the Tualatin River.

CONCLUSIONS

The USGS has spent almost a decade studying water quality in the Tualatin River Basin. That investigation characterized the sources of water and nutrients to the river, measured the dynamics of the phytoplankton population and the sources and sinks of dissolved oxygen, and generated insight into the possible effects of numerous management alternatives on the river's water quality.

Several paradigms were challenged during this study. Background phosphorus levels were measured and found to be much higher than originally expected. This background is natural, fed by a large supply of highly mobile phosphorus in ground water from the upper 500 feet of valley-fill sediments throughout the basin. The high background phosphorus level will make attainment of the original phosphorus TMDL difficult, if not impossible. SOD was discovered to be the largest overall consumer of DO in the river, and SOD is not driven primarily by decomposing phytoplankton. Because phytoplankton are not tied directly to the SOD and because photosynthetic production is the largest overall source of DO to the river, a small phytoplankton population at times actually is beneficial to the river's DO. In addition, now that WWTP effluents are low in phosphorus, the resulting increased discharge in the river improves river quality in many respects.

The original Tualatin River TMDLs currently are being reassessed. The USGS investigation of water quality in the Tualatin River Basin has aided in identifying issues that are central to that reassessment. USGS personnel are working with ODEQ and river management agencies such as USA to provide technical information for the creation of revised TMDLs for the Tualatin River.

ACKNOWLEDGMENTS

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MANAGEMENT AGENCY PERSPECTIVES ON THE TMDL PROCESS FOR THE TUALATIN RIVER BASIN, OREGON[1]

Lori Faha[2]

Abstract. *The Unified Sewerage Agency (USA) is a utility providing sewer and stormwater management services to the urban portion of Washington County, Oregon. The service area is approximately 120 square miles, including nearly 400,000 customers, and is located entirely within the Tualatin River basin. The Oregon Department of Environmental Quality established initial Total Maximum Daily Loads for the Tualatin River in 1988 for total phosphorus and ammonia. USA, as one of 9 Designated Management Agencies (DMAs) in the watershed, has TMDL requirements for its wastewater treatment plant discharges and for its storm and surface water management program.*

This paper summarizes some of the key successes, problems and challenges related to the Tualatin Basin TMDL program. The upshot is that pollution control programs have been largely successful. The river now usually meets key water quality standards. The tributaries also show improving trends for water quality. However, stream health problems still persist, and additional water quality parameters of concern have been identified. Challenges and disagreements between regulators, management agencies, and citizens continue regarding what are the most appropriate target pollutants and sources, and appropriate target concentrations, especially given unique physical characteristics of the watershed. Additionally, it is an ongoing challenge to agree on and effectively measure the success of individual management practices. Meanwhile, the DMA s continue to implement numerous pollution control efforts, and the watershed is much healthier as a result.

BACKGROUND

The Unified Sewerage Agency (USA) is a special service district, providing sanitary sewerage, sewage treatment, and stormwater and surface water management in the urban portions of Washington County, Oregon. The USA's service area of 120 square miles is located entirely within the Tualatin River watershed. There are 12 cities, plus unincorporated areas located within USA's service district, and the total population served is nearly 400,000. Intergovernmental Agreements define roles, responsibilities, and funding splits between the cities and USA. Generally, USA operates the wastewater treatment plants, operates and maintains the major sanitary and storm systems, and establishes the minimum standards for maintenance, new development and construction practices. There are many tributary streams to the Tualatin River that are located all or partly within USA's service area. These streams are typically somewhat degraded in streambank and habitat conditions and have poor water quality relative to temperature, dissolved oxygen and bacteria. These conditions are generally due to the impacts of previous agricultural activities and current and increasing urbanization. Water quality problems can also be exacerbated due to summer low flows; the Tualatin Basin is entirely storm and groundwater driven with no snowmelt sources of flow.

TMDLs were initially established by the Oregon Department of Environmental Quality (DEQ) for the Tualatin River in 1988. This followed a 1986 lawsuit in which the Northwest Environmental Defense Center prevailed over EPA, who agreed that the TMDL provisions of the Clean Water Act (Section 303) were not being implemented in Oregon. The Tualatin River was the first waterway to subsequently receive TMDLs. The problems in the Tualatin River were low dissolved oxygen, nuisance algal growth, and pH violations. Ammonia and phosphorus were targeted by DEQ as needing control before the river could meet water quality standards. USA received waste load allocations for ammonia and total phosphorus for its wastewater treatment plants. Additionally, target instream concentrations and draft load allocations for nonpoint sources were established for total phosphorus. USA was listed as a Designated Management Agency (DMA) for its service area. (Other DMAs are: the Oregon Department of Agriculture, Oregon Department of Forestry, the Cities of Portland, Lake Oswego and West Linn, and Washington, Clackamas and Multnomah Counties.)

In subsequent years, USA has instituted various planning and implementation efforts for the wastewater treatment plants, urban stormwater and streams. The wastewater treatment plants have more than achieved the TMDL lim-

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*
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its, by constructing advanced wastewater treatment systems and increasing river flow augmentation at a cost of $200 million.

On the stormwater/tributary stream side, despite much effort by many DMAs, original deadlines for meeting TMDL target concentrations and proposed LAs were not met. A compliance schedule listing various required BMP s for all DMAs was established by DEQ in 1993. While USA has complied with the BMP requirements, the compliance schedule deadline has been moved several times because the streams still were not meeting the numerical TMDL targets.

USA, the US Geological Survey (USGS), and others have performed intensive monitoring and modeling as a means to analyze water quality trends and program performance and to better understand how the river and tributaries work. This data has proven useful in all these areas to USA. However, the data has also been used now by DEQ to list the Tualatin and now its many tributary streams on the 303(d)(1) list as water quality limited for additional parameters (primarily temperature, bacteria, dissolved oxygen, and for fish communities).

WHAT IS A TMDL?

In addition to the background information presented, an understanding of TMDL regulations is necessary before some of our issues as a DMA can be understood or appreciated.

Section 303(d)1 of the Clean Water Act requires that states (or EPA) must identify waters not meeting water quality standards and establish Total Maximum Daily Loads for them to restore water quality. Water quality standards are established by states or EPA to support the attainment and maintenance of beneficial uses (such as swimming, fishing, habitat, municipal/industrial use, etc.). A Total Maximum Daily Load is the amount of a pollutant that can be assimilated by a waterway and still meet water quality standards. TMDLs are divided into separate load limits for point and non-point sources, background levels, and a reserve (for uncertainties in the analysis, and for allowances for growth). Waste Load Allocations (WLA) are set for point sources (effluent limits) and Load Allocations (LA s) are set for non-point sources.

This can be described by the following simple equation:

Stream Capacity = Background + WLA s + LA s + Reserve

WLAs typically are expressed as effluent limits in National Pollutant Discharge Elimination System (NPDES) permits for wastewater treatment plants and industrial dischargers. The WLAs may be more stringent than standard effluent limits or may be in addition to such limits in the NPDES permits.

On the urban stormwater and nonpoint source side it gets more complicated. The typical conveyor of nonpoint pollutant loads is stormwater runoff (although other sources such as irrigation return flows and lack of shading vegetation can also be contributors). Runoff picks up soil particles and pollutants in variable quantities depending on a number of conditions including: land use, soil type, slope, vegetation or cover, imperviousness, amount and intensity of rainfall, the time since the previous rainfall, etc. Typically, various Best Management Practices (BMPs) would be applied by the DMA as a condition of the TMDLs. The cumulative impact of all applied BMP s should result in achieving the LA:

Land Loads - BMP s = LA

These equations seem simple and straightforward. The idea behind TMDLs is certainly appealing and seems to represent common sense: determine a stream's capacity for pollutants of concern and limit all loadings at or below that capacity.

USA's TUALATIN TMDL EXPERIENCE: WHAT WE'VE ACCOMPLISHED

There have been remarkable improvements in water quality in the Tualatin River due primarily to wastewater treatment plant improvements. This represents a $200 million investment by USA's ratepayers in innovative advanced treatment systems. Some of the systems and technology did not exist anywhere prior to establishment of the stringent TMDL regulatory requirements.

With the exception of a couple of rural tributaries on which substantial agricultural pollution sources were identified and reduced or eliminated, most of the tributaries to the Tualatin River have not seen the substantial phosphorus reductions exhibited by the main river. Data analysis does show a small improving trend in terms of slight phosphorus reductions during the summer compliance period in the tributaries.

However, since USA began its surface water management (SWM) program in 1990, many BMP s have been implemented. There has also been significant urban development since that time as well. Figure 1 shows total phosphorus concentrations over time on Fanno Creek, an urban tributary to the Tualatin River. The figure also shows the growth of Equivalent Dwelling Units (EDUs) over time (a reflection of new development). There are a number of possible interpretations of this figure:

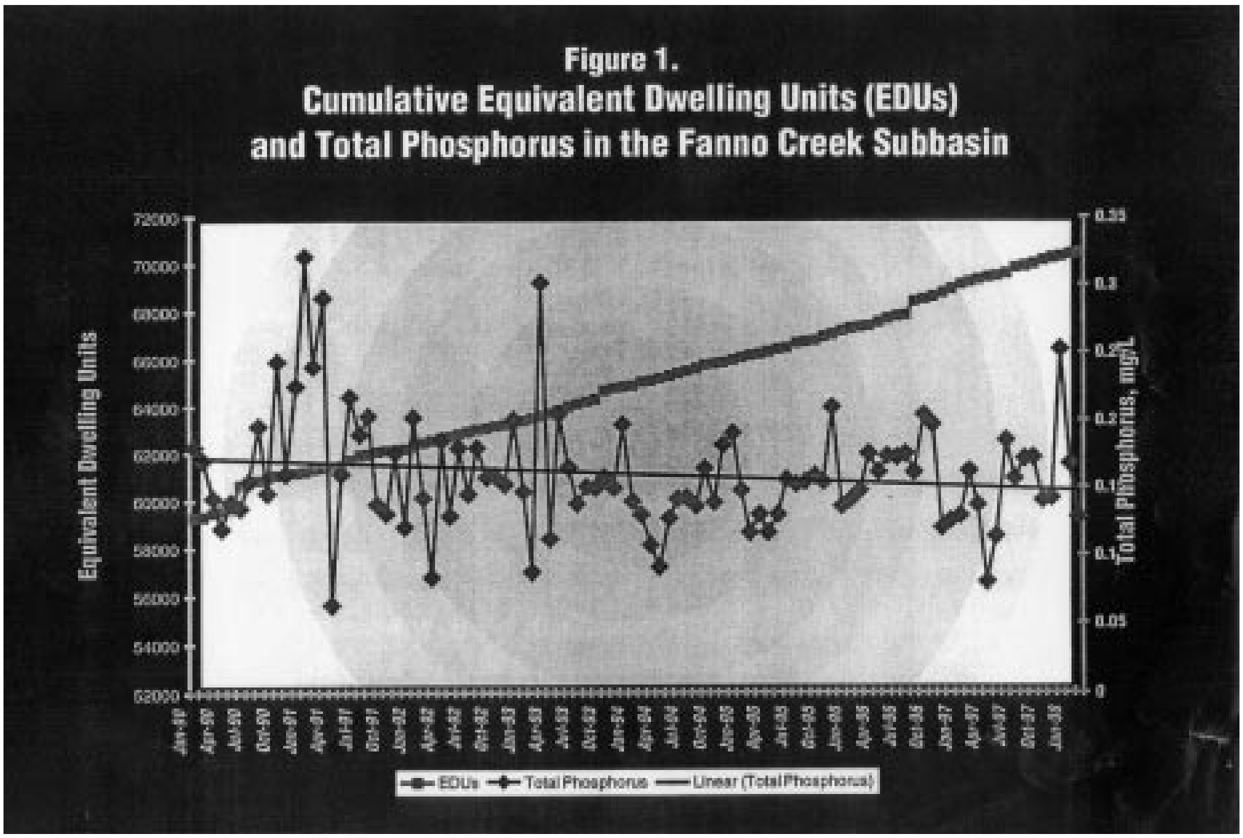
Figure 1.
Cumulative Equivalent Dwelling Units (EDUs)
and Total Phosphorus in the Fanno Creek Subbasin
Equivalent Dwelling Units
Total Phosphorus, mg/L
EDUs
Total Phosphorus
Linear (Total Phosphorus)

Figure 1.

Implementation of BMPs, especially those aimed at reducing pollutants from new development, have been successful. This assumes that without the BMPs, the total phosphorus would have increased with increasing development and impervious surfaces.

Neither BMPs nor new development has a significant impact on ambient total phosphorus concentration instream.

Figure 2 shows Fanno Creek water quality trends as measured by DEQs Water Quality Index. The Water Quality Index provides a single number representing water quality conditions based on the following parameters: temperature, DO, BOD, pH, total solids, ammonia + nitrates, total phosphorus, and fecal coliform. The purpose of an Index is to try to represent overall stream health, which generally can't be well represented by a single parameter. Fanno Creek remains in what DEQ terms the poor category, but there is a significant improving trend exhibited on the graph, again despite substantial new development, and this would seem to imply that application of BMPs has in fact been successful and should be continued.

Table 1 summarizes the general type and extent of BMP s applied by USA across its service district since 1990, along with assumptions as to their effectiveness in addressing specific pollutants and sources (reference: Technical Review of Nonpoint Sources of Phosphorus and Total Maximum Daily Loads for Tributaries in the Tualatin Basin, Tualatin Basin Technical Advisory Committee, Nonpoint Source Subcommittee, May 1997).

We have also learned much about how the Tualatin River and its tributaries work. USA, in partnership with the USGS, Oregon Graduate Institute (OGI) and others, have spent substantial effort to better understand this complicated, highly manipulated, slow-moving river system.

USA's TUALATIN TMDL EXPERIENCE: REMAINING ISSUES & PROBLEMS

After 10 years of TMDLs and substantial efforts by DMAs, there continues to be debate about what is achievable in the Tualatin River and its tributaries, and whether the management measures being implemented are the right ones at the right level of effort. The meaning of the results of scientific efforts meant to better understand the river system is being debated. It s complicated. Everyone s goal is to support the appropriate beneficial uses in this watershed, but what is necessary and achievable remains open for interpretation. There are several key issues that are unresolved including:

How to best use the available data and science

How to deal with unknowns

How to apply a numerical standard to variable, hard to measure nonpoint sources and management practices

These are critical issues that must be resolved before TMDLs can be effectively applied in any type of watershed context. Unfortunately, after 10 years, these issues have yet to be resolved in the Tualatin Basin. Meanwhile, DEQ is in the process of a fast-track revision of the Tualatin Basin TMDLs, which will provide updated phosphorus and ammonia numbers, and new TMDLs for the additional parameters on the 303(d) list for the basin streams (temperature, bacteria, DO, fish communities). Within a few months, DEQ must take the substantial amount of science, together with the also substantial amount of unknowns, and create achievable TMDLs, LAs and WLAs that are designed to bring the river and streams into compliance with water quality standards.

In the Tualatin Basin, the DMA s support the use of good science as a basis for the establishment and enforcement of TMDLs, and are willing to live with the results. In our situation, the scientists from USGS, OGI, USA and other organizations are essentially making a case that existing programs adequately control the human sources of phosphorus, and the focus should now be on other stream health problems. There are a few parties who don't agree with the findings and conclusions of these scientists that background levels of total phosphorus in the river system are naturally high due to natural groundwater and geologic conditions. The contention is that human sources, especially in urban areas, cause the higher phosphorus, and that removing the phosphorus will address the other stream health issues. This is an important disagreement, because it impacts the whole focus of future efforts.

The DMAs feel it is time to focus on other key water quality issues such as temperature and DO, which directly impact the critical beneficial use: cold water fish. Increased removals of phosphorus does not necessarily translate into benefits to these parameters.

The DMAs have a concern that third parties are at times given too much influence because they threaten lawsuits against the regulatory agencies. This can lead to adoption of non-science based numerical limits and/or unrealistic compliance time frames. DMAs with existing permits (National Pollutant Discharge Elimination System NPDES permits for wastewater treatment plants, industrial discharges, or municipal stormwater systems) are particularly at risk for an inappropriate level of liability. This is because these numbers can be placed into their permits by the DEQ, and the DMAs are then subject to substantial violation fines and third party lawsuit provi-

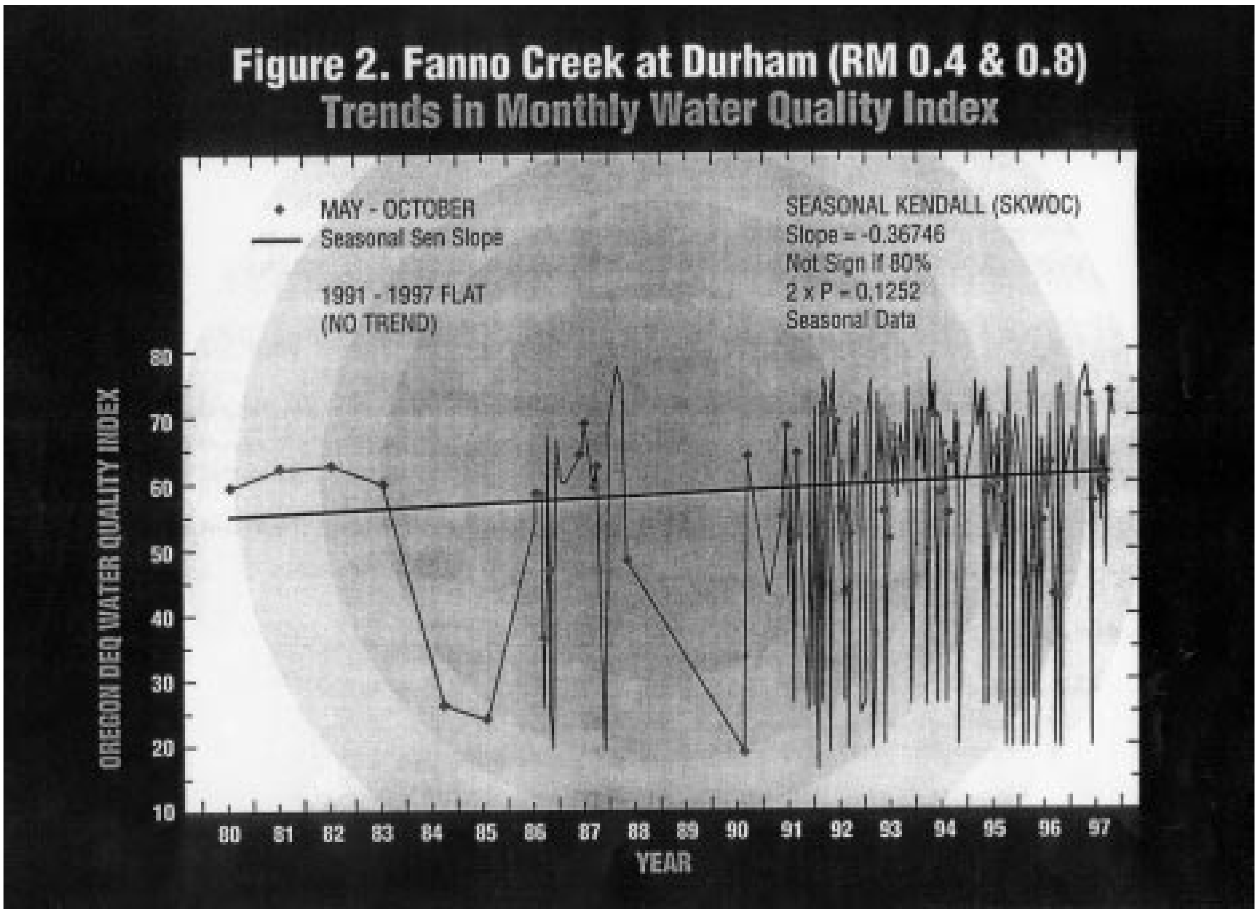
Figure 2. Fanno Creek at Durham (RM 0.4 & 0.8)
Trends in Monthly Water Quality Index
MAY - OCTOBER
Seasonal Sen Slope
1991 - 1997 FLAT
(NO TREND)
SEASONAL KENDALL (SKWOC)
Slope = -0.36746
Not Sign if 80%
2 x P = 0.1252
Seasonal Data
OREGON DEQ WATER QUALITY INDEX
80
70
60
50
40
30
20
10
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

Figure 2.

Table 1.
SUMMARY OF USA'S BEST MANAGEMENT PRACTICES
AND RELATIONSHIP TO POLLUTION SOURCES

	USA 1	USA 2	USA 3a	USA 3b	USA 3c	USA 3d	USA 4	USA 5	USA 6	USA 7	USA 8	USA 9	USA 10	USA 11	USA 12	USA 13	USA 14	USA 15
	public education	const. site erosion con.	Grassy Swale	Ret/Det Pond	Leaf Compost Filter	Extended Dry Detention	buffer codes	regional WQFs	stream veg. enhancemt & bioengr.	catch basin cleaning	Storm sewer line cleaning	street cleaning	ditch maint. & re-seeding	WQF Maintenance	TV storm lines disconnect ill. connects.	small grants for enhancmt to comm. grps	Small Farm Technical assist	review industries for DEQ storm permits
DEGREE OF IMPLEMENTATION	W	W	W	S	R	W	W	R	S	W	W	W	W	S	W	S	S	S
POTENTIAL SOURCES OF TOTAL P																		
Surface Water																		
Roads & ditches	N	N	M/L	M/L	M/L	M/L	N	M/L-M	N	M/L	L	L-M	L-M	L	N	N	N	N
Parking lots & Roof Tops	L	N	M/L	M/L	M/L	M/L	N	M/L-M	N	M/L*	L	L-M*	L*	L	N	N	N	N
Fertilizer	L	N	L	L	L	L	L	L	L	L	N	L	L	L	N	N	L/M	N
Manure - Livestock	L*	N	N	N	N	N	M-H*	N	M-H*	N	N	N	N	N	N	N	M	N
Manure - Pet Waste	L	N	L	L	L	L	L	N	L	L	N	L	L	N	N	N	N	N
Septic System Failures	L*	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Upland erosion	L	H/M	L	M/L	M/L	M/L	L	L	L	M/L	L	M/L	L	L-M	N	L	M	N
Decomposing Vegetation	L*	N	N	N	N	N	M?*	N	L-M?*	L	N	N	L	L	N	N	L-M	N
Landslides	N	M/L	N	N	N	N	L	N	L	N	N	N	N	N	N	N	N	N
Illegal Dumping	L	N	N	N	N	N	N	N	N	L	L-N	N	N	N	L	N	N	L
Illicit discharges	L	N	N	N	N	N	N	N	N	N	N	N	N	N	H	N	N	L
Streambank/bed erosion	L	M	L	M/L	N	M/L	H/M	M/M-L	H/M	N	N	N	N	N	N	M-H	M	N
Groundwater																		
Manure storage ponds	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dry wells	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Soil Short Circuits	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atmosphere																		
Dust	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
POTENTIAL SINKS OF TOTAL P																		
Upland Vegetation	L	L	L	L	N	L	N	L	N	N	N	N	L	N	N	N	N	N
Riparian Vegetation	L	L	N	N	N	N	H	M	H	N	N	N	N	N	N	H	M	N
Soils	L*	N	M/L	H/L	N	M/L	L	M-H/L-M	L	N	N	N	L	N	N	N	N	N
IMPACTS ON OTHER POLLUTANTS																		
DO/SOD/BOD	L	H/M	M/L	M/L	M/L	M/L	M-H	M/L	M-H	M/L	L	L-M	L	L	L	M	L-M	L
temperature	L	N	N	N/-	N	N	L/H	L/M	L/H	N	N	N	N	N	L	L/M-H	L/M	L
bacteria	L	N	L	M/L	M/L	L	M	L	M	L	L	L	L	L	M-H	L	M-H	N
instream flows	L	N	L	M	N	L	M	L-M	M	N	L	N	L	N	N	L-M	N	N
TSS	L	H/M	M-H/L	H/L	H/L	M-H/L	M/L	M-H/L	M	M/L	M/L	M/L	M/L	L	N	M-H	M/L	L
metals	L	L	M-H/L	M-H/L	H/L	M-H/L	L-N	L-M/L	N	L-M	L	L-M	N	L	L-M	N	N	L-M
organic toxics	L	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	L-M	N

KEY:

Relevance: X = Not relevant to pollutant or landuse in the Tualatin Basin

Degree of implementation when or where effective:
W = Widely used
S = Sometimes used
R = Rarely used

Effectiveness in the Tualatin Basin:
N = Not effective at reducing the pollutant
L = Low degree of effectiveness at reducing the pollutant
M = Medium degree of effectiveness at reducing the pollutant
H = High degree of effectiveness at reducing the pollutant
\- = Has an adverse environmental impact
* = Not currently used in this application

Wet / Dry: Season of impact: If the degree of implementation or the effectiveness is different for the WET and DRY season indicate the WET value on the left of a " / " and the DRY value on the right of a " / " in the spreadsheet cell.

Wet – Winter - Ground Saturated - Significant amount of rain - Signigicant amount of runoff
Dry – Summer - Ground not saturated - Very little Rainfall - Very little runoff
If Best Management Practice treats runoff - On "Dry" side note "X" for Not Relevant or "L" for Low degree of effectiveness

NOTES:
BMP USA-1: water quality effectiveness of public education actions are essentially impossible to measure, therefore low rating was given to be conservative, however, this is still considered to be a very valuable/necessary BMP
BMPs USA 3b, 3d, 5: retention/detention ponds (on-site and regional) are built off-line from streams, so temperature impact is expected to be negligible to none.
BMPs USA 5, 11: WQF = water quality facility

sions of the Clean Water Act, even if the numbers are not substantiated.

An important question is how literal of an interpretation should be taken of the Clean Water Act Section 303: are TMDLs just that: total maximum daily loads, not concentrations, not lists of BMPs, or any other measurements? One theory seems to be that DMAs should be able to readily calculate land surface loadings, as well as pollutant removal rates for all BMPs. This supports the literal interpretation of the equation LAs = Loadings BMPs. This theory assumes that each DMA should be able to just bean-count their way to program development and compliance, and that this will automatically provide for water quality standards to be achieved instream. This sounds great and straightforward, but unfortunately, reality does not support the theory; at least not in the Tualatin Basin.

There are usually a multitude of types and combinations of BMPs that can be implemented, each on at various levels of effort or frequency. There is limited data on specific pollutant removal effectiveness for most BMPs. A quick review of the various BMP categories listed in Table 1 should clarify for anyone that many of the practices, while beneficial, are difficult if not impossible to measure for pollutant removal. There is even less information or data available that relates BMPs to direct instream impacts or benefits. Plenty of variables and data gaps also exist on the pollutant loading side; land uses and sources, and rainfall-runoff patterns are extremely variable. Another substantial information gap exists regarding what portion of available pollutants actually enters the streams and the level of impact of intermittent loadings on stream health parameters.

Estimating land loadings and subtracting off BMP removals (when it can even be estimated) involves piling assumption on top of assumption. This exercise can have some utility for comparing several BMP implementation scenarios. However, if this information is used to create and justify load allocations, and the numbers are then placed in permits, DMAs may be subject to enforcement actions due to circumstances beyond their control, and at the mercy of gross assumptions of effectiveness.

We need to develop a method for applying the intent of Section 303 of the Clean Water Act to the nonpoint source and stormwater management arena. The method needs to allow for the uncertainties, unknowns, and unmeasurable aspects of nonpoint sources and related BMPs, while achieving stream health improvement over time.

WHERE DO WE GO FROM HERE?

The case history of the Tualatin Basin illustrates that the implementation of TMDLs must be done in an iterative fashion. It is highly unlikely that adequate information will be available in any watershed to pick the right pollutant parameters, set the right numbers, and immediately implement all the necessary practices to achieve water quality standards the first time around. It should be assumed that parameters, numbers, and practices will have to be reviewed and revised over time.

There is a need to develop a regulatory methodology that addresses the inherent uncertainties and unknowns associated with stream processes and land sources. The key is to ensure that the land managers and point source managers are tied to enforceable programs. This does not necessarily mean that all sources must be given a number of pounds of pollutant reduction they must achieve. DMA compliance must be based on implementation of plans and practices approved by the regulatory agency, that are based on common sense, sound science, and the best available information.

DMAs must select BMPs based on supportable methods. This can be done by involving technical and citizen stakeholders in evaluation processes to compare various BMPs based on multiple criteria. BMPs can be given relative ratings for criteria such as whether they would be expected to have a positive, neutral, or negative impact on various water quality parameters, cost, maintainability, impacts to habitat, safety, aesthetics, and others. BMP frequency or level of effort can be initially based on industry standards, on estimated amounts of material removed vs. cost, or could be tested first in a small geographic area. These are reasonable and justifiable methods for selecting program elements, and allow for the use of various BMPs that are either unmeasurable or have never been measured for the pollutant at issue.

Adequate time must be given for BMPs to be implemented and to have the results realized. Building facilities such as wetlands requires substantial permitting. BMPs that include vegetation, such as tree planting to reduce temperature, may take several years before any positive results can be expected. Meanwhile, DMA compliance can be based on how many, how frequently they are implementing the BMPs.

If management practices can be measured for direct pollutant removal from the stream, by all means they should be measured and counted, and enforcement should be based on such measurements. But in the many cases for nonpoint sources and stormwater systems where this cannot be done, the compliance paradigm must be changed to account for the reality.

Ultimately, the goal is to achieve water quality standards and support beneficial uses. Measures of success must be determined that represent this goal. We can focus on pollutant load counting exercises or we can let the stream tell us if we re on the right track. If a TMDL program is working, stream health data trends should show movement toward the goal. If such trends are not apparent, the regulatory agencies and DMA s must re-evaluate both the TMDL targets and their implementation programs for adequacy and appropriateness. The upshot here is that the DMAs don't want to get hung over bean counting issues if the stream is in fact improving.

Water quality goals can be achieved through good science, good judgement, and implementation of management plans. Application of the Clean Water Act laws, including adequate enforcement mechanisms, is possible, even when the real world doesn't readily fit into a few simple equations.

Lori Faha

THE GARCIA EXPERIENCE: A SEDIMENT TMDL CASE STUDY[1]

Robert R. Klamt[2]

Abstract. *Salmon and steelhead play a significant role in California north coastal economy, philosophy, and politics. Author Mark Twain is credited with saying that in the West, whiskey is for drinking and water is to fight over. More recently on the north coast, the fight has focused on salmon and land use. Continued concern for the anadromous fisheries has turned attention from the water itself to the riparian zone and hill slopes of the steep erosive coastal mountains of northern California.*

The Garcia River is a coastal tributary located about 100 miles north of San Francisco Bay. It is forested with commercial conifers and hardwoods and supports farming and cattle and sheep ranching. Historic waves of logging activity at different levels of regard for the land and water resources coupled with erosive soils on steep slopes and high winter rainfall resulted in significant erosion and sedimentation. Concern over declining anadromous salmonid populations brought attention to sediment impacts in the Garcia River watershed. That focus and threat of a lawsuit prompted the development of a sediment reduction strategy (TMDL) that addresses habitat and channel structure in the waterways by requiring landowners to submit erosion control plans. In May of 1998 the North Coast Regional Water Quality Control Board adopted a TMDL and implementation plan with the assistance of the US Environmental Protection Agency. Controllable sediment discharges are prohibited, and reductions of sediment delivery to streams from roads, timber harvest, and agriculture are required on a 40 year time table. Instream numeric targets that describe the desired future condition of the riparian area, stream channel, and fish habitat are used as goals to measure the success of the reductions over time. The development of the TMDL and, especially, the implementation plan were contentious and involved numerous public workshops and hearings over a 2 year period. However, landowner response and attitude and, subsequently, the nature of land use activities is slowly changing. Landowner inventories and monitoring will provide a physical assessment of watershed recovery. The response of the fisheries will tell the ultimate story.

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

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INTRODUCTION

The Garcia River is a cold-water northern California coastal tributary about 100 miles north of San Francisco Bay. The watershed is approximately 73,223 acres in size and forested with conifers (primarily redwood and fir) and hardwoods (mainly tanoak and madrone). A defining feature of the basin is the San Andreas fault, which controls the drainage pattern in the watershed, including the Garcia mainstem which follows the fault for about 15 miles. Land use impacts can be pronounced due to high rainfall (45-75 average annual rainfall) and steep slopes combined with erodible and unstable geology.

Ten landowners comprise about 80% of the land ownership in the watershed. Primary land use is timber production, with grazing/ranching second. Industrial timberland comprises about 52% of the land mass in the watershed, currently under three ownerships. Noncommercial timber harvest occurs in the mixed conifer and oak woodland areas as well, and farming is done in the lower 5-7 miles of the watershed.

The watershed has experienced three waves of logging activity:

1) The first major logging activity occurred in the late 1800s to about 1915. A number of mills and log flumes were erected in the watershed and nearby providing building lumber, shingles, and railroad ties as the main commodities.

2) In response to the post-world War II demand for new housing and the advent of the crawler tractor, another period of major logging activity occurred in the 1950s and 1960s. With this new found technology and the demand for lumber products the watershed was logged again with little regard for the stream and watershed health. Tractor yarding down streams and ephemeral draws was common, and an extensive road net work was developed to remove large volumes of timber.

3) The most recent activity has been in the last decade, with 52% of the watershed entered for timber harvest in the period 1987-1997, with over 40% of that logging in 1988 and 1989. About 84% of the 1980s and 1990s logging used tractor yarding. While silvicultural and harvest methods were much improved with the adop-

tion of the Forest Practice Rules in the mid-1970s, the reentry into the watershed involved extensive reopening of road networks and land disturbance associated with the road and skid trail network.

The Garcia River watershed was placed on the Clean Water Act Section 303(d) list along with 17 other watersheds in 1992 for salmonid fishery impairment from sedimentation. The Regional Water Board confirmed that listing in 1994 and subsequent listings. Section 303(d) requires the State to develop a waste reduction strategy (called a Total Maximum Daily Load) to reduce loading and bring the water body into compliance for the listed pollutant. A lawsuit was filed in 1995, contending the State failed to adopt TMDLs on those water bodies in a timely fashion, and that USEPA is required to develop and adopt TMDLs in response to the Section 303(d) listings. A consent decree resulted that set a schedule for the adoption of 38 TMDLs on those 17 north coast streams in a decade. Since the State could not adopt the Garcia TMDL by the deadline, USEPA adopted a TMDL in March of 1998. The Regional Water Board subsequently adopted a TMDL in May of 1998. This paper is a summary of the TMDL development process based largely on information provided in Mangelsdorf and Lundborg (1997) and NCRWQCB (1997).

The listing was supported by declines in salmonid stocks including extirpation of pink and chinook salmon and dramatic declines in coho salmon and steelhead. Coho are estimated to have declined to less than 10% of the 1960s estimated escapement of 2000 adults. Steelhead are estimated to have declined 87% from historical numbers in the Northern California Evolutionary Significant Unit overall. Physical evidence of sediment impacts were also part of the listing criteria and included channel aggradation, channel widening, filling of pools, and increased levels of fine sediments in spawning gravels.

GARCIA RIVER WATERSHED GROUP

A watershed group was formed in 1990 under a California Coastal Conservancy grant to address watershed health issues associated with salmonid declines. The result of that two year effort was the Garcia River Watershed Enhancement Plan (MCRCD 1992), which contained a strong fisheries emphasis. Since the plan came from a collaborative process with a group with wide representation, we felt it a perfect opportunity to develop a TMDL in a similar manner.

We reorganized the watershed group and began an open public process to develop the TMDL and an implementation plan in 1996. The intent was to have the watershed group collaboratively develop a statement of desired future conditions (numeric instream targets), assist in analyzing source areas and developing load allocations, and to collaboratively develop an implementation plan. The implementation plan, as a necessary outgrowth of the TMDL process, would provide the framework to address existing sediment sources and provide guidance on land use practices to preclude the development of new sediment sources and reduce sediment discharges overall.

BASIC TMDL APPROACH

The approach we embarked on with the watershed group first was to assess existing watershed conditions: where and what categories of problems and sources were responsible for sediment discharges. Development of desired future conditions would provide a yardstick to judge the extent to which the identified sources were contributors to a fishery problem, as well as specific parameters against which success of the implementation strategy in the long term would be evaluated. A limiting factors analysis would provide the linkage between the identified sources and problems and impairments relative to the desired future conditions. The load allocations were an outgrowth of the resource assessment and sediment budget, providing a picture of the relative contributions of source categories to impairments in the watershed. And, finally, the allocation of responsibility laid out the strategy and schedule for implementing: specific actions to address existing problems, plans for sediment reductions from current and future land use practices, and monitoring of the implementation activities and the river s response to implementation actions.

RESOURCE ASSESSMENT

The assessment was primarily concerned with up slope conditions as they related to watershed function with an erosion and sediment delivery emphasis, including: geomorphology, riparian function, hydrologic change, and active erosional processes.

The mapping of geologic and geomorphic features by the California Division of Mines and Geology (1984), aerial photo interpretation, erosion hazard rating calculations conducted by timber companies as part of their Timber Harvest Plans from 1987 to 1997, and the geologic and erosion hazard information from the Louisiana-Pacific Corporation (L-P Corp 1997) were used as the basis for the geomorphology assessment.

Pacific Watershed Associates (1997) used a modification of the RAPID analysis (Grant 1988) for the riparian function assessment, analyzing changes in stream channel opening throughout the watershed for the period of 1952 through 1996. Riparian zone mapping and analysis from Circuit Rider Productions, Inc., included in Philip Williams and Associates (1996), augmented the above information, along with soils and vegetation, habitat typing, and instream cover data from the Natural Resource Conservation District, Mendocino County Resource Conservation District, and California Department of Fish and Game.

Hydrologic changes were assessed using existing data and literature reviews to develop some broad hypotheses and recommendations.

The assessment of active erosional processes relied heavily on modifications of the methods used in Washington state (WDNR 1995). Data sources included aerial photos (1966-1996) and existing data on roads, stream classes, watershed boundaries, and topography provided as geographic information from Timber Harvest Plans submitted to the California Department of Forestry and Fire Protection from 1987 through 1997.

Geomorphology

The Garcia River watershed is relatively steep and unstable with numerous parallel faults along the San Andreas fault zone. Much of the landscape is dominated by large translational/rotational slides, earth flows, debris slides, and other unstable areas. Garcia watershed soils are erodible, with erosion hazard ratings predominantly in the medium category, high and extreme ratings occurring in several of the major tributaries and upper stream reaches.

Riparian Function

Although significant recovery has occurred since 1966, the riparian zone has not fully recovered since the large-scale timber harvesting operation of the 1950s and 1960s as determined from channel widening observations since 1952. Accordingly, many of the reaches have poor canopy closure, including poorly developed overhanging vegetation and undercut banks. In general, the riparian zone in a large part of the watershed is comprised of deciduous trees and shrubs with few conifers, additionally affecting the amounts and future recruitment of large woody debris.

Hydrologic Change

There were not sufficient data to determine changes in the hydrologic regime as a result of land use activities over time. However, increased impervious surfaces (roads and landings) and compacted soil areas decrease summertime base flow and increase runoff and storm flows. Roads and skid trails also interrupt the natural drainage patterns down slopes, affecting the hydrology to an unknown degree.

Erosional Processes

Four primary processes or mechanisms were identified: 1) mass movement (landslides), 2) fluvial erosion (gullies, road and skid trail crossing failures, stream bank erosion), 3) surface erosion (rills and sheetwash), and 4) land management activities which directly place soil in stream channels. The analysis resulted in a watershed sediment budget detailed by category (Table 1). The primary land management activities contributing sediment were roads and skid trails, timber harvest areas, and agricultural activities.

Sediment yields in Caspar Creek to the north, which was well-studied with regard to overall sediment yields associated with different management practices, was used to estimate an overall sediment yield reduction. For the Garcia River watershed a 52% reduction was calculated and an additional 8% margin of safety applied to account for uncertainty in the analysis. While the reduction was not directly, nor quantitatively, tied to the numeric instream targets, it represented what could be done on the hill slopes and in the riparian zone to improve conditions in the Garcia.

LIMITING FACTORS ANALYSIS

A limiting factors analysis was performed using a team approach, drawing from professionals familiar with the species and the watershed. All available information was gathered from sources such as agency files (Department of Fish and Game, Department of Forestry, etc.), timberland owner forestry management plans, anecdotal information from landowner interviews, and restoration and environmental groups. The team of professionals, representing the major disciplines of geology, forestry, fisheries, soils science, engineering, and hydrology, evaluated the information and developed a limiting factors statement for each sub-watershed (CalWater Planning Units). The stream channels have experienced changes in response to pulses of sediment moving through the system. Aerial photo analysis for a 44-year period from 1952 pointed out channel widening as evidenced by increased stream openings, and a narrowing of the channel as the sediment pulse moved through. Some stream sections opened again and others are still recovering.

Associated with those sediment pulses are changes in fish habitat and access, realized as filled pools, low frequency of pools, high gravel embeddedness, fine sediment in spawning gravels, small gravel particle sizes overall, low occurrence and recruitment of large woody debris, broadening of the stream which enhances solar warming and affects spawner access, and deltas or subgravel flows from some tributaries effectively blocking spawner access to natal streams.

NUMERIC INSTREAM TARGETS

Numeric instream targets were developed from information in the literature. Little information was available for

TABLE 1.

Estimated sediment sources for the Garcia River watershed on an annual basis.

Sediment movement mechanism	Percentage of overall budget	Estimated average annual sediment yield (tons/mi^2/year)
Sediment Inputs		
Mass wasting	40 - 60%	560 - 840
Fluvial erosion	26 - 45%	364 - 630
Surface erosion	10 - 21%	140 - 294
Total inputs		1,400 (median)
Movement of Stored Sediment		
Gravel extraction	77%	586
Streambed erosion *	23%	174
Sediment Outputs		
Bedload and suspended sediment	100%	2,160

* 174 tons/mi^2/year were not specifically estimated in the sediment budget, and may be instream stored sediment as depicted in this table or represent inaccuracies in the estimates.

Robert R. Klamt

the stream itself or parallel watersheds. Targets were developed as expressions of desired future conditions for fish access and habitat, sediment metering and transport functions, and channel stability.

Targets associated with spawner migration and spawning success included: 1) barriers to access (no barriers), 2) percent fines <0.85 mm in spawning gravels (14%) and percent fines < 6.5 mm in spawning gravels (30%). Salmonid rearing targets included: (1) pool depth (>3 feet), (2) pool width (maximum width > width of low flow channel), (3) pool length (maximum length > width of low flow channel), and (4) pool frequency (primary pools as define by depth, width, and length of 40%).

Channel structure and stability targets included: (1) V* (percent of residual pool volume filled with sediment, <21% mean, and <45% maximum), (2) median particle size (d50, >69 mm mean, 37 minimum), (3) large woody debris (improving trend),(4) width to depth ratio (improving trend corresponding to predicted Rosgen (1996) channel type), (5) thalweg profile (increasing variability about the mean thalweg for a reach), and (6) stream openings (improving trend specific to identified stream reaches).

IMPLEMENTATION PLAN

The development of the implementation plan was the most difficult and contentious element. Views were expressed from widely divergent perspectives. We used a combination of material on existing land use practices effects on erosion, input from the Garcia River Watershed Group, and the judgment of professionals in the agencies and the field to develop the final implementation plan. Our perspective was to focus the implementation on the hillslope and riparian areas, because it is generally known what types of activities cause or exacerbate erosion and riparian destruction.

Since a direct quantifiable linkage was not available between how much of an activity on the hillslope will cause a consequent impact in the stream and how that translates to the fishery, we focused on a plan that would identify sediment sources, address those sources, and produce site specific plans to reduce erosion and sedimentation from future activities. The logic was that preventing erosion to the extent practicable and allowing the watershed to restore function for handling sediment would result in attainment of the instream numeric targets by the year 2048. As new data are developed with implementation of the TMDL, the overall sediment reduction estimate of 60%, the numeric targets, and the overall implementation strategy will be revisited and refined if appropriate.

<u>Discharge Prohibition</u>

The region-wide prohibition on discharge of " ...soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity ..." in amounts that are " ...deleterious to fish, wildlife ..." was changed to a full prohibition on controllable discharge and the activities broadened to add gravel mining, agriculture, and grazing. Controllable discharges are defined as " those discharges or depositions resulting from human activities" ... and that " ... can be reasonably controlled through prevention, mitigation, or restoration."

The effect of that prohibition was to broaden its applicability in recognition of the impaired status of the Garcia River. The prohibition does not apply to landowners implementing an approved erosion control plan, providing incentive for landowners to develop those plans.

<u>Erosion Control Planning</u>

Two options were provided in terms of erosion control plans: 1) watershed-wide default measures, or 2)a site-specific plan developed by the landowner that meets the intent of the default measures. The watershed-wide default measures are taken in large part from existing California Forest Practice Rules, but go beyond those regulations in requiring such things as leaving trees in the riparian zone and unstable areas and restricting harvest for the first 25 feet of the riparian zone where bank stability is an issue. The default measures were developed to: 1) provide landowners with a clear picture of the measures that would reduce erosion and improve the overall watershed health for fishery production, and 2) provide small landowners that do not want to do a site-specific plan the option of using default measures.

All landowners are required to assess existing sediment delivery sources and prioritize those sites for remedial actions to reduce sediment delivery. In addition, management measures to ensure that new controllable sites are not created and that conditions are allowed to improve are required. Both aspects of management are required in a plan to be submitted to the Regional Water Board within three years.

<u>Allocations Of Responsibility</u>

The Implementation Plan also sets out specific dates for compliance by source category and activity. Sediment source sites must be addressed according to a schedule:

> Sediment source and unstable areas inventory - 3 years, and every 10 years thereafter

Roads - 10% of the sites per year, final date is 10 years after inventory

Timber harvest operations and associated activities - 10% of the sites per year, final date is 10 years after inventory

Agricultural operations on hillslope and riparian areas - 20% of the sites every four years, final date is 20 years after inventory

Additionally, landowners are required to monitor their sediment source mitigations for effectiveness and report the results annually. A broader monitoring program to track the instream numeric targets is planned, but the level and frequency of sampling will be determined by budget constraints. We are looking for ways to fund or partner in the monitoring.

CONCLUSIONS

The experience of developing the TMDL and implementation plan overall was one of learning as you go. While we had every intent of a collaborative development of the plans, the time was not right in the Garcia River watershed. However, the watershed group provided a wealth of information and perspective to the process, improving communication and educating one another (the agencies included) in the process. While a totally collaborative approach may not be possible all the time, involvement of landowners and other interest groups is a necessary and crucial part to developing any watershed plan. Since TMDLs are regulatory in nature, the public process is all the more important.

The testing of the methodology has provided a firm basis for assessing other watersheds that require TMDLs for sediment. In that regard, the lessons learned will improve efficiency and effectiveness. Data availability is still an issue - obtaining the data from private companies as well as attempting to collect new data for the assessment. While significantly reducing the uncertainty associated with a paucity of data may not be feasible given funding constraints and time, the uncertainty should be quantified to the extent possible. Phased TMDLs also provide the opportunity to improve the knowledge base for future revision and fine-tuning of the TMDL.

Development of numeric targets put into one place on the California north coast an assessment of the literature and some attempt to interpret narrative standards. The exercise produced a valuable product that will be used in future TMDLs, but also will be refined in the future.

Most significant is the change in attitude regarding management of hillslope and riparian resources with respect to the streams in the Garcia River watershed. While there has been consistent and persistent distaste for the regulatory nature of the TMDL and implementation plan, landowners are coming forth with plans to assess their properties, address sediment delivery sources, and manage their activities in a manner that is more fish friendly. The process is a long one, but we are seeing change now that will have a positive effect on the future of anadromous salmonids in the Garcia River watershed.

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USING SURROGATES FOR STREAM TEMPERATURE NONPOINT SOURCE WATER QUALITY LOADING ALLOCATION[1]

Karl Gebhardt[2] and Helen Fisher[3]

Abstract. *Allocating the loading of water quality pollutants has become an important priority for water quality managers around the United States. Point source allocation has dominated past efforts, particularly with the EPA's Total Maximum Discharge Loading (TMDL) program. However, on much of the western forest and range land, TMDL assessment and allocation must consider loading almost exclusively from nonpoint sources. In these cases, the assessment is usually straightforward. The allocation can be far more difficult. Nevertheless, water quality managers must move toward nonpoint pollutant allocation under the Clean Water Act.*

Surrogates for a pollutant loading allocation may provide a relatively inexpensive means of setting and assessing water quality goals where watershed management problems are dominated by nonpoint sources. This paper provides criteria for considering the general application of surrogates and focuses on applying aspects of shade from riparian vegetation as a potential surrogate for thermal loading.

INTRODUCTION

Early this year the Environmental Protection Agency approached us with a proposal to look at the possibility of using surrogates in their Total Maximum Daily Load (TMDL) efforts on the South Steens grazing allotment in eastern Oregon. Specifically, the EPA was interested if surrogates for temperature loading and sediment loading could be developed for application on western forest and range land. The primary reason for this was to develop cost effective and workable measures where direct measurement was impractical. In addition, EPA required a basis for using surrogates that would be acceptable to their attorneys. This paper, which was prepared in draft at the time, was utilized by EPA in developing the concepts behind the use of surrogates for temperature loading in the South Steens allotment.

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THE NEED FOR SURROGATES

Instream problems associated with water quality attributes such as temperature and sediment are generally easy to identify. Setting realistic values for attainability, on the other hand, can be far more difficult. Monitoring significant progress towards meeting attainability goals can also be difficult, particularly when change is slow, difficult to detect, and dependent on many variables. Surrogates can be useful where they help simplify the attainability goal and improve monitoring. In some cases, surrogates may offer the only short term measure of trend where measuring the attribute itself would yield results of little or no significance. Most importantly, where a surrogate is highly correlated to the attribute, it may provide a better overall means relating to a load allocation that the attribute itself.

One or more of the following cases may justify the consideration of surrogates:

- Direct data concerning the water quality attribute may be difficult to obtain.
- Reasonable estimates on the potential improvement of an attribute may be difficult and/or expensive to determine.
- Once implementation of a Water Quality Restoration Plan is in place, the attribute alone may not be sensitive to improvement, particularly in the short term.
- Monitoring the attribute alone may be inefficient or inconclusive.

CRITERIA FOR CONSIDERING SURROGATES - A SCREENING TECHNIQUE

Surrogate water quality attributes should possess characteristics that will provide the water quality manager with better investigation and assessment tools than using the water quality attribute alone. The following are offered as a minimal criteria for considering surrogates.

A strong predictive relationship exists between the surrogate and the water quality attribute. - The scientific literature should support relationships between the surrogate and the water quality attribute to the extent that predictive tools have been established. In the best case this would be quantitative models, in the minimal case this would be strong observational, qualitative relationships.

The surrogate offers measurement stability. - If the surrogate does not readily change during a 24-hour period or from day to day, it is considered stable. The surrogate may be changing, but the rate of change does not confound the ability to compare a measurement within a measurement window of a few hours to a few days.

The surrogate can be modified by management (i.e., a manageable characteristic). - The purpose of a Water Quality Restoration Plan is to make positive change in water quality. Inherent in this goal is the assumption that the water quality attribute is manageable and therefore the surrogate must be manageable.

The surrogate is as sensitive to management change as the water quality attribute. - The surrogate should show change at least commensurate with management's induced change on the water quality attribute.

The surrogate should be a primary limiting factor of the water quality attribute. - This implies that the surrogate's effect on the water quality attribute is significant.

The surrogate can be remotely sensed. - This is a particularly useful characteristic because of the large extent of western range and forest land. Remoteness and lack of personnel may not allow a water quality attribute to be measured regularly or even during important time periods.

RIPARIAN VEGETATION AS A SURROGATE FOR TEMPERATURE LOADING

The following sections present a discussion of riparian vegetation and related factors pertaining to the criteria for considering surrogates developed above.

A strong predictive relationship exists between the riparian vegetation and stream temperature

Temperature has been studied in streams for many years and relationships describing the behavior of temperature are well documented (Brown 1970, Meehan 1970, Theurer et al., 1984). An examination of the major physical processes affecting stream temperatures suggest that shade, provided by riparian vegetation, is likely the most important manageable characteristic affecting these processes for streams of low discharge and high width/depth ratios. Bartholow (1989) provided a sensitivity analysis for the SNTEMP model (Theurer et al., 1984) for maximum and mean water temperatures to various variables. His analysis showed air temperature, shade, relative humidity, stream flow, inflow temperature, and stream width to be the most important variables affecting change in mean and maximum daily water temperatures. The major variables he analyzed included: water temperature, air temperature, percent shade, relative humidity, stream flow inflow temperature, stream width, solar radiation, travel time, wind speed, ground temperature, percent possible sun, and thermal gradient. Of the variables listed above, excluding water temperature, air temperature, percent shade, stream flow, inflow temperature, stream width, and wind speed can be considered manageable to some degree.

Air temperature as used in the context of stream temperature modeling, is generally the ambient local temperature and may be susceptible to anthropogenic climate effects, is not considered manageable for the purpose of this discussion. However, the effect of management on the microclimate (within 2 meters of the ground) cannot be ignored and vegetative shade must be considered the primary agent.

Percent shade is the percent of stream that is shaded by topography and vegetation. Obviously, percent shade is directly related to riparian vegetation where topographic shading is not important.

Stream flow is the discharge of the stream and to some extent may be manageable through reservoir management and through changes in vegetative cover of the watershed. However, it is not significant to this discussion.

Inflow temperature is the temperature of tributary water entering a stream. While manageable in the watershed context it is not important to this discussion since all of the variables pertinent to this discussion would likely apply to a tributary stream as well.

Stream width is the wetted width of the stream. This variable has been shown to be very manageable in many situations depending on the morphology and physical process affecting the stream system. Riparian vegetation can be a limiting factor in maintaining the width of the stream commensurate with the bankfull width expected for a stream's particularly basin characteristics. Where vegetation is disturbed or missing altogether, stream width may be excessive.

Wind speed is considered the velocity of the air above the stream. Although highly variable, wind speed can be managed through increasing the surrounding vegetation . In nearly every case these manageable variables are to some degree dependent on riparian vegetation.

Process-based stream temperature models rely on estimates of riparian vegetation to provide for a shade input to the stream. They do not, however, consider some of the other important functions that vegetation plays to the other variables. Thus, there is a fairly well established relationship between riparian vegetation and shade.

Riparian vegetation offers measurement stability

Temperature varies considerably over a short period of time while riparian vegetation remains constant providing an advantage in determining trend over time.

Riparian vegetation can be modified by management (i.e. a manageable characteristic) Riparian vegetation is very responsive to management in most cases.

Riparian vegetation is as sensitive to management change as water temperature

If shade provided by riparian vegetation is significant in modifying solar loading, and therefore temperature change, and also is sensitive to management change then it follows that some aspects of the riparian vegetation are as sensitive to management as a temperature measurement. Riparian vegetation may show significant change prior to any effect on shading, and therefore prior to temperature effects. If, upon maturity, the riparian vegetation can reduce solar loading, then the trend in vegetative growth can be useful in assessing progress towards meeting attainment objectives.

Riparian vegetation is the primary limiting factor of stream temperatures in many cases Riparian vegetation should be the primary manageable limiting factor provided the potential vegetation will provide significant shade. Riparian community types are described in a number of documents covering the western United States. Kovalchik (1987) describes riparian associations and community types for parts of Oregon. His descriptions contain information on the potential natural vegetation and seral vegetation likely to inhabit an area. The potential effectiveness of the vegetation in providing adequate stream shade therefore is dependent on the site supporting the species capable of providing shade along with the management to allow the species to reach maturity. Other variables such as discharge and width need to be evaluated along with the potential shade to determine the significance of the shade, and therefore the vegetation, to stream temperature management.

Riparian vegetation can be remotely sensed

Nearly all vegetative attributes affecting shade can be remotely sensed using aerial photography (Clemmer, 1994). This provides a significant advantage to the land manager who needs to monitor trend over a large area or where land ownership, topography, or other obstacles are not conducive to field monitoring. The Northwest Watershed Research Center (C. Slaughter, pers. com.) is currently working on advanced videographic techniques to measure vegetation and stream geometry attributes.

APPLYING RIPARIAN VEGETATION AS A SURROGATE

The criteria for surrogates developed above present a logical argument for consideration of a surrogate. Perhaps the most important criterion to applying a surrogate is its role as a limiting factor. Therefore, vegetative shade, as a primary limiting factor, should be evaluated before proceeding to use it as a surrogate. The following questions can help make this evaluation.

> Does the vegetative community type support species capable of producing significant shade based on the width of the stream?
>
> Does the stream flow and stream width suggest that shade will be significant over the reach?
>
> Are there sources of water (tributary, lateral ground water, discrete ground water) that significantly affect the stream's temperature in the reach?

The last question can be evaluated by tributary-specific review to locate segments that may have significant influence on the reach being studied. The first two questions can be evaluated using vegetation classification and geomorphology relationships in addition to temperature modeling.

Background

A stream typical of eastern Oregon was selected for a generic application of the surrogate screening criteria. Field data suggested some streams in the Steens grazing allotment managed by the U.S. Bureau of Land Management may not always meet summer temperature criteria important to the Catlow redband trout (Oncorhynchus mykiss ssp.). Temperatures have been shown to exceed the Oregon water quality standard, which is 64^{o} F. (17.7^{o} C.) Temperature is one of several variables degrading habitat that may be limiting the distribution of the species. The cause of the degradation has been attributed to a long history of livestock grazing leading to a lack of woody riparian vegetation, unprotected streambanks, and poor structure due to sediment.

Streams in the allotment supporting the redband trout headwater on a plateau and proceed into canyon valley types. The width of the valley bottom supports the notion the stream was formed during a wetter climatic regime of Late Pleistocene.

<u>Method</u>

Two stream temperature models, SNTEMP (Theurer et al. 1984), and Heat Source (Boyd 1998) were used to simulate downstream temperature change based on a variety of vegetation community types expected during recovery. SNTEMP was selected because it has been well tested and supported by the U.S. Fish and Wildlife Service. Heat Source was selected because it was a newer model designed for diurnal variation as well as having an automated sensitivity analysis feature.

The models were parameterized using a 9 km (5.6 miles) reach of Home Creek in eastern Oregon. One typical cross section was used to represent a 1 km and 9 km reach since the purpose of the analysis was to demonstrate the effects of vegetative shade on temperature change and not to simulate the actual conditions of Home Creek. A constant discharge of 0.14 cubic meters per second (5 cubic feet per second) was used. The drainage area is approximately 56.9 square kilometers (22 square miles) which suggests an expected bankfull channel width of about 6 meters (20 feet) estimated from a regional curves for the Owyhee river basin (Figure 4). The typical elevation used was 5900 feet (1798 m) taken from the USGS 7 ´ minute quadrangle maps.

Several riparian community types were used to help portray the expected vegetative conditions and response to improved management. The general descriptions found in Draft Catlow Redband Trout and Catlow Tui Chub Conservation Agreement and Strategy (1998) suggest the potential natural community for the stream is likely a dense willow community often surrounded by aspen groves. Riparian zone associations developed by Kovalchik (1987) were used to help estimate an ecological successional pathway for the area. Kovalchik's work contains typical species composition, density ranges, and management information for many riparian communities in Oregon.

The following riparian types were used to approximate potential riparian shade parameters for the models.
Potential Natural Community- Mature PNC-M

> *Willow/aquatic sedge nearest the stream surrounded by quaking aspen on the outer edges. Willow species dominated by Geyer willow, Booth willow, and Lemmon willow. Willow shade characteristics in excellent condition: shade height = 5 m, width > 4 m, density > 0.8. Quaking Aspen shade characteristics in excellent condition: shade height = 10 m, width > 4 m, density > 0.8.*

PNC-Y- young phase

> *Young willow. Shade characteristics: shade height = 3 m, shade width = 1.5 m, density = 0.5.*

PNC-I- immature

> *Willow. Shade characteristics: shade height = 1 m, shade with = 1 m, density = 0.5.*

D-1 - Degraded phase

> *Willow/Kentucky bluegrass. Shade characteristics range from none to shade height < 3 m, width < 1 m, density < 0.2.*

D-2 - Degraded phase - Sagebrush.

> *Shade characteristics: shade height < 1 m, width < 1 m, density 0.5.*

Models were run for extreme high temperature conditions to simulate effects related to the limiting water quality standard. Average daily temperatures were on the order of 21^{o} C (70^{o} F), with a maximum to 32^{o} C (90^{o} F).

<u>Results</u>

Results for a 9 km reach are presented in Figure 1 below based on the SNTEMP model. Similar results were found with the Heat Source model, however, the maximum daily results with little or no shade exceeded reasonable expectations. Therefore, the data are not presented. The differences between the temperatures in each step in the ecological progression were comparable however. The differences are the very important to the overall point for using surrogates. For example, if one were to attempt monitoring temperature alone in the first 1 to 5 years, few if any measurements would yield statistically significant results. Whereas, if vegetation was used for monitoring, it would yield trend information immediately.

The models were run at a variety of temperature regimes, width, and discharge to demonstrate the sensitivity. Figures 2 and 3 presents a variety of downstream temperature results for a 1 km (3000 ft.) reach using an initial average daily upstream temperature of about 11° C for changes in discharge and stream width, respectively.

Figure 2 demonstrates the sensitivity of discharge in temperature determination. Where discharge is low, shade and therefore riparian vegetation may be a good surrogate to consider. Where discharge is large, riparian vegetation may be the only attribute to consider, since temperature will be very insensitive.

Figure 3 demonstrates change in temperature per km based on width and shade conditions. Shade becomes a very important factor on wide streams with low discharge, and therefore vegetation also provides a very good surrogate.

CONCLUSIONS

Riparian vegetation appears to be a good surrogate to temperature attainability goals where it is a limiting factor. Vegetation allocation for riparian areas could be made in such a manner as to require certain communities in certain densities which would minimize stream temperature problems. Riparian classification tools could be used directly to help water quality managers set realistic attainability goals rather than goals developed from less persuasive sources. Where the screening criteria presented apply, it appears that proper use of riparian vegetation monitoring can provide water quality managers with a very powerful and sensitive tool towards temperature loading questions.

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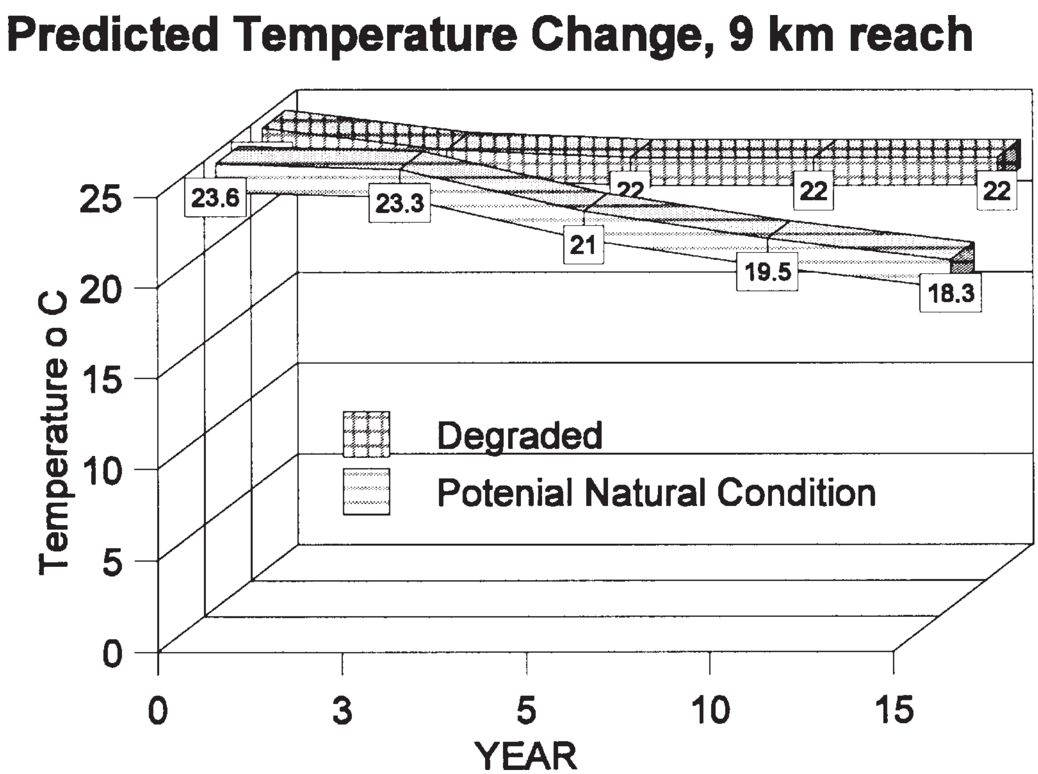

Figure 1. Projected temperature changes based on ecological community.

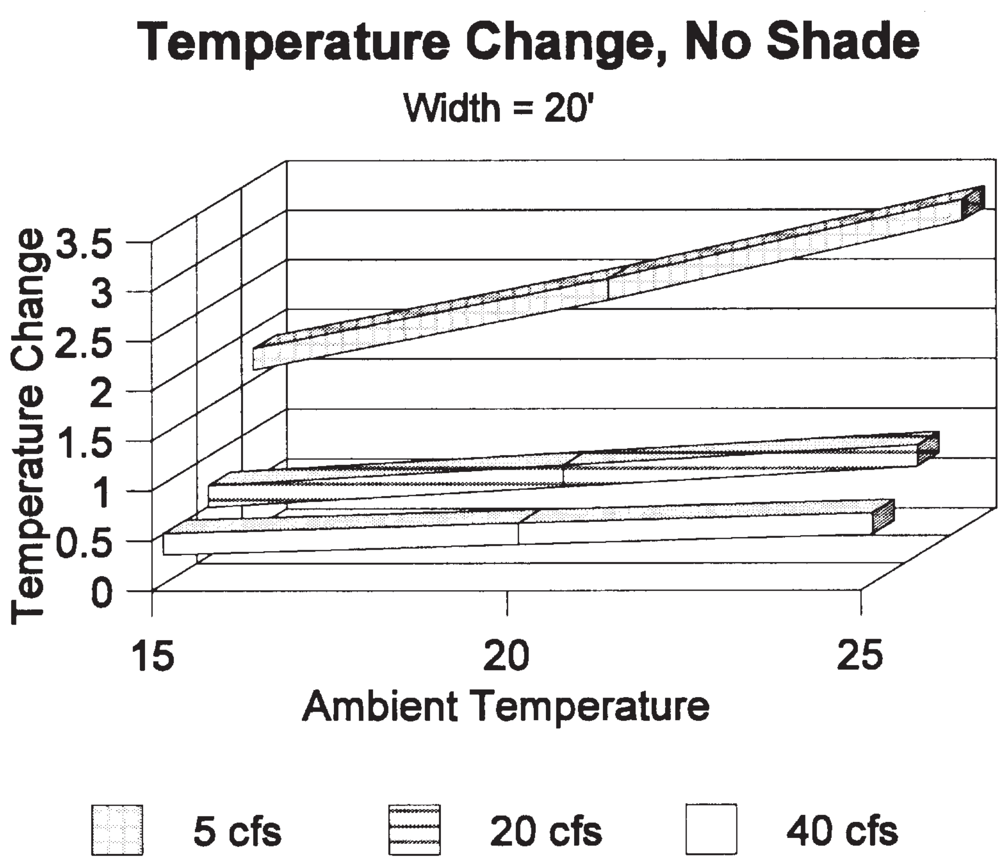

Figure 2. Change, based on width and shade conditions.

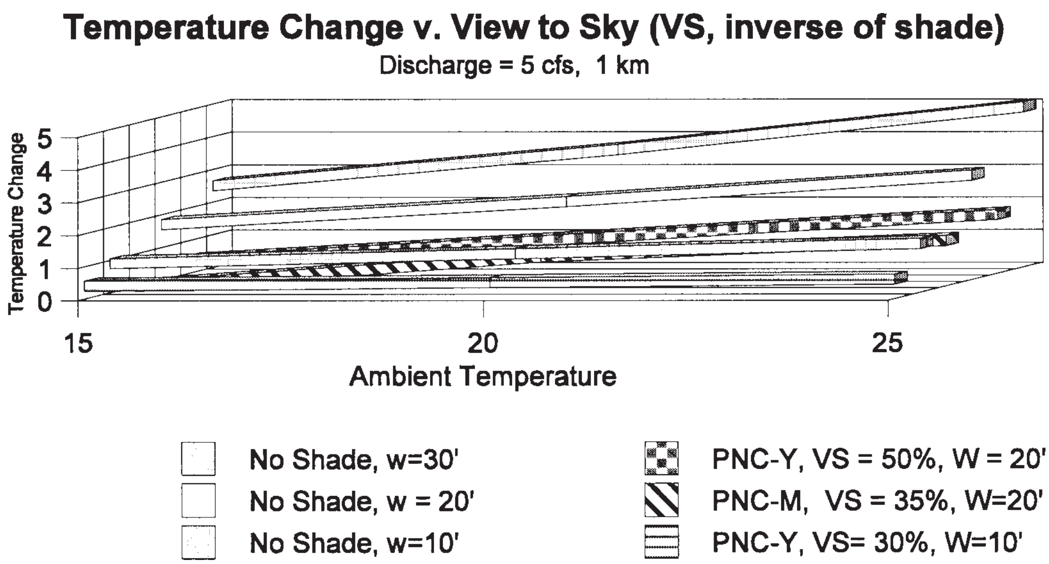

Figure 3. Change, based on width and shade conditions.

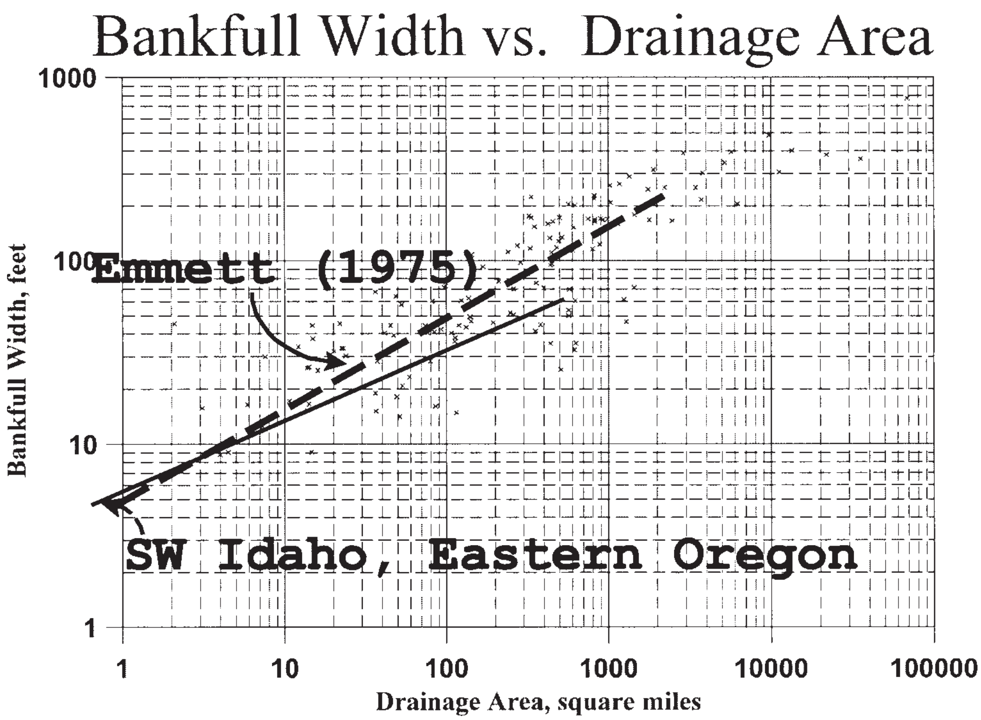

Figure 4. Regional Curves for Southwest Idaho, Eastern Oregon

Plenary Session

COOPERATIVE WATERSHED STRATEGIES: COMBINING SCIENCE AND SENSE

Organizer: *Sari Sommarstrom*
Sommarstrom & Associates
Etna, California

WATERSHED MANAGEMENT COUNCIL

FIVE YEARS OF COLLABORATIVE SUCCESS ON THE HENRY'S FORK[1]

Janice M. Brown[2]

Abstract. *The Henry's Fork Watershed Council is celebrating five years of meaningful dialogue and successful collaboration since it began in November 1993. Co-facilitated by the Fremont Madison Irrigation District and the Henry's Fork Foundation, the Watershed Council continues to serve as a constructive, inclusive forum for sharing scientific data, policy perspectives and citizen initiatives. Some 40-60 people attend regular Council meetings, which are now held bimonthly with special field trips, workshops, and subcommittee meetings held in alternate months.*

The Henry's Fork Watershed Council serves as an Idaho Watershed Advisory Group (WAG) for the purposes of advancing water quality and responding to 303(d) listings within the watershed. Realizing that certain non-listed streams also had water quality problems, the Council has successfully advanced a stream restoration project on Sheridan Creek, which was awarded an EPA 319 grant in May 1998. This $248,000 project will restore streamflow to the natural stream channel by repairing up to ten diversion structures over the next four years. Fish passage, bank stabilization and riparian revegetation and protection are also factored into the project, which involves several land management agencies and private land owners.

The Council's most recent initiatives include formation of a Native Trout Conservation Subcommittee in order to be proactive with respect to a potential listing of Yellowstone Cutthroat Trout. A comprehensive native trout survey has been supported by Council funds, and a pilot project to transplant cutthroat into Harriman State Park is still in the planning stages. Finally, a subcommittee was recently appointed to study the effects on the Henry's Fork basin if an additional million acre-feet of Upper Snake River water is procured for salmon flush on the Lower Snake.

In addition to these high-profile efforts, the Watershed Council regularly critiques and helps fund creative projects sponsored by individual Council participants. These have included Trumpeter swan relocation strategies, noxious weed inventories, research on natural springs sources, interpretive signage and publications, and innovative stock watering and rotation grazing projects. These projects must receive consensus support through the Council's Watershed Integrity Review and Evaluation process, which permits thorough discussion among the many agencies, scientists and citizens in attendance.

[1]Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).

[2]Henry's Fork Foundation, P.O. Box 61, Island Park, Idaho 83429

GRANDE RONDE MODEL WATERSHED PROGRAM "PARTNERSHIP FOR SUCCESS"[1]

Patricia N. Perry[2]

Abstract. *In April of 1992, the Grande Ronde Basin was selected by the Northwest Power Planning Council as the model watershed project in Oregon. The program is to serve as an example for the establishment of watershed management partnerships among local residents, state and federal agency staffs, and public interest groups concerned with the management of a particular watershed. The central strategy of the approach is based upon the belief that a locally based effort to improve coordination, integration and implementation of existing local, state, and federal programs can effectively protect, enhance, and restore a regional watershed area.*

The program covers the Grande Ronde Watershed area in the Blue Mountains Region of northeastern Oregon and comprises approximately 5,300 square miles, and 280 rivers and streams containing over 2,600 miles of fisheries. Land ownership in the basin is approximately 65% public and 35% privately owned.

The purpose of the model watershed program is to coordinate the goals and objectives of all interests in order to use available natural, human, and fiscal resources within the watershed in the most beneficial manner. A comprehensive watershed management approach is used to enhance and expedite implementation of activities to identify knowledge and program gaps, resolve conflicts, and formulate priorities for action. Both public and private lands are included in the process through voluntary participation in the program activities.

PROJECT BACKGROUND

With the imminent Endangered Species Act (ESA) listing of spring chinook salmon on the horizon, the Union County Commission and Wallowa Court determined that a grass-roots, locally based effort working to coordinate existing local, state, and federal programs could effectively maintain, enhance, and restore our watershed. Joining in this effort, the Northwest Power Planning Council selected the Grande Ronde basin as a model watershed for Oregon, and the Governor's office through the Strategic Water Management Group certified the program. Bonneville Power Administration provides the administrative funding.

Appointed in May 1992, the Grande Ronde Model Watershed Program Board of Directors (Board) represents a diverse group of interests with the common vision of a healthy watershed. Participants include stock-growers, farmers, tribes, environmentalists, elected officials, and public lands, community, forestry, and fish and wildlife representatives.

A watershed can be managed to:

- Maintain and enhance natural aquatic biological diversity
- Enhance or protect threatened species populations.
- Maximize natural resource yields in wildlife, water, commodities, or human uses.
- Support the economic and social livelihood of a community.

With that understanding, the Board formulated a mission statement which incorporates many of these elements. It is to "develop and oversee the implementation, maintenance, and monitoring of coordinated resource management that will enhance the natural resources of the Grande Ronde basin." Although addressing multiple elements in watershed restoration is perhaps more difficult than pursuing a single purpose, the Board felt this approach essential.

The basin encompasses the Blue Mountains region of northeastern Oregon. It is approximately 13,689 km^2 (5,265 mi^2) in size and has 280 streams and rivers containing over 4,160 km (2,600 mi) of fisheries. Land ownership is approximately 65 percent public and 35 percent private. The basin supports numerous healthy populations of fish and wildlife, as well as the ESA-listed spring chinook salmon.

INITIAL STEPS

An important first task was developing memorandums of understanding to create partnerships with local residents, state and federal agencies, tribes, and interest groups concerned with the management of the Grande Ronde watershed. From there, stream survey data available from state

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[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

[2]*Grande Ronde Model Watershed Program, 10901 Island Avenue, LaGrande, Oregon 97850*

and federal agencies were compiled into a Habitat Assessment. This assessment was peer reviewed and accepted by the Board. This provided a sound "starting point" to develop a plan and focus restoration activities.

A technical committee was formed consisting of biologists, hydrologists, a soil scientist, forester, and other resource specialists to advise and provide recommendations to the Board on planning direction, technical issues, and to review and evaluate project proposals for technical merit and adequacy. Local agency staffs, the tribes, and private individuals with technical expertise are playing a crucial, key role in the model watershed process by serving on this committee. Reviewing project proposals has become one of the main functions of the technical committee, and is an effective means for ensuring cooperation and coordination among agencies and the various projects and activities in the basin.

MODEL WATERSHED ACTION PLAN

Next, the Grande Ronde Model Watershed Operations Action Plan was prepared. It serves as a basin-wide framework to identify priority (for spring chinook salmon) subwatersheds for more detailed planning. It incorporates information gathered from several prior planning documents as well as the Habitat Assessment. The plan includes restoration criteria to aid in the process of prioritizing project actions. Staff is continuing to develop detailed subwatershed plans and project actions, working with landowner groups and others as appropriate. Landowner participation in this process is completely voluntary.

Additionally, the model watershed program initiated the Grande Ronde Ecosystem Diagnosis and Treatment (GREDT) study. This was undertaken to provide technical information to the Board and technical committee in their effort to plan and implement watershed restoration activities. The study was motivated by a need for a science-based methodology that promotes effectiveness and accountability. The analysis focuses on spring chinook salmon, which serves as a diagnostic species in assessing the condition of the watershed for sustainability of its resources and related societal values. This study assumes that humans and their values are integral parts of an ecosystem and that human communities within the Grande Ronde basin desire a healthy watershed that can sustain natural resources as well as economic and social values for future generations.

An effectiveness monitoring strategy has been developed and incorporated in program activities. On-going monitoring efforts will be identified, coordinated, and used to establish gaps that need to be addressed. Each project action also contains a monitoring component. Some projects include monitoring by local high school students.

The Grande Ronde Model Watershed Program serves as an educational forum for landowner groups through coordination with the Oregon Cattlemen's Association and local Soil and Water Conservation Districts. Additionally, the model watershed program is defining for itself a role as facilitator of improved dialogue between local, state, tribes, and federal natural resource management agencies. The model is especially helpful in encouraging coordination on issues beyond normal jurisdictional boundaries, and creating cooperative and incentive-based ways to encourage private landowners to take part in restoration efforts.

HABITAT RESTORATION PROGRESS

The model watershed program has assisted in developing many project proposals for habitat restoration in the basin. These projects involve private landowners, schools, organizations, tribes, and local, state, and federal government agencies. Funding has been recommended and secured for approximately 230 worthy, well-designed projects. These projects address factors such as:

Fish passage structures/irrigation diversion improvements.

Riparian and rangeland livestock management/off-stream water development.

- Sediment.
- Erosion reduction.
- Water quality and quantity.
- Fish habitat.
- Technical seminars addressing riparian grazing.
- Education.

Implementation of these projects is in various stages, with most of them completed, while others are presently ongoing. Funding for these projects is available through private landowners, Governor's Watershed Enhancement Board, Bonneville Power Administration, Bureau of Reclamation, and other state and federal agency programs, as well as private groups and organizations.

Long-term project planning is ongoing, creating an advantage in securing and utilizing habitat restoration funds as opportunities arise. Project proposals in priority subwatersheds are developed with the objective to address identified environmental conditions such as fish passage problems, substandard riparian conditions (i.e., streambank erosion, streambed sedimentation, altered channel morphology, loss of pools, and reduced habitat complexity), upland conditions producing sediment, poor water quality, and depleted flow conditions.

In conclusion, the Grande Ronde Model Watershed Program is an exciting and innovative experiment in citizen-based natural resource planning by coordinating among all entities involved in watershed activities in the basin and is charged with providing a model for other watershed basins to consider.

CONSIDERATIONS

It takes time to create partnerships and develop a strong basin council. Being based in local county government has been very positive and offered additional opportunities. A watershed council must allow for a diverse group of interests, local agendas, and perspectives.

Planning is vital before moving to projects. The key is a local assessment of environmental conditions in order to establish priorities driven by the local governments, agencies, tribes, and community. The time expended for this is also well utilized in developing local consensus and unity.

Project development is very time consuming, and many local entities must be involved and incorporated in the process. Implementation is a multi-year process, recognizing our actions today will make a difference in the quality of our environment 25-50 years from now.

The availability of administrative and technical assistance/support to the watershed council is a crucial component.

Patricia N. Perry

CALIFORNIA'S FEATHER RIVER STORY — SURVIVING THE TEST OF TIME[1]

Donna Lindquist[2]

Abstract. *The Coordinated Resource Management (CRM) process has been used successfully in many states to provide a framework for resource enhancement efforts. This process allows for more effective development and implementation of solutions to cross-jurisdictional problems, particularly where multiple landowners, competing land use, large geographic areas and resource degradation trends are at hand. The Feather River CRM (FRCRM) began in 1985 as a partnership of 17 public and private sector groups. In 1988, the CRM process was formally adopted as a vehicle to facilitate a broad scale watershed restoration program, that included the 3,222 square mile upper Feather River watershed. The impetus for the group's formation, which now includes 21 partners, was widespread erosion in the upper watersheds and subsequent sedimentation in hydropower dams downstream in the Feather River canyon. A strategic watershed approach was initiated by the FRCRM that evolved from a series of watershed inventory and assessment studies, a river basin plan, and input from local landowners, academics and resource agencies. These activities formed the basis for an erosion control strategic plan that was developed to guide watershed restoration activities. The FRCRM has undertaken over 50 restoration projects and watershed studies since 1985. The restoration effort has evolved from a focus on demonstration projects that treat sediment supply problems mid-level in the watershed, to restoring the water and sediment retention and release functions in headwater reaches.*

INTRODUCTION

The Feather River Coordinated Resource Management group (FRCRM) is an alliance of 21 natural resource management agencies, local land owners, academia, public and private sector groups working towards restoration of California's Feather River watershed. Since 1985, the FRCRM has implemented over 50 restoration projects, which were planned and funded by watershed partners. Since inception, members of the FRCRM recognized the critical link between watershed condition and local economic stability, and the important role restoration plays in sustaining this balance. Building stakeholder partnerships was identified as the best vehicle to achieve restoration goals, which promoted adoption of the CRM approach.

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

[2]*Plumas Corporation, 91 Church Street, Quincy, California 95971*

The Feather River watershed includes 3,222 square miles of land base that drains west from the crest of the northern Sierra Nevada into the Sacramento River. Water produced from these watersheds provides over 1,400 MW of hydroelectric power, and represents a significant component of the State Water Project, annually providing 3.2 million-acre feet for urban, industrial and agricultural consumers downstream. Timely delivery of high quality water is becoming more imperative as demand increases. Restoration and maintenance of headwater systems is critical to meeting future demand since the quantity and quality of California's water supply is dependent upon the condition of source watersheds.

The Feather River watershed has been affected by 140 years of intensive human influence. Extensive mining, grazing, timber harvesting, wildfire, railroad, and road construction and maintenance have contributed to watershed degradation, resulting in accelerated erosion, sedimentation in streams and reservoirs, and degraded terrestrial and aquatic habitats. Restoration of watershed function is a key element in reversing these trends. Stable, well vegetated streams with functioning meadows, aquifers and uplands are critical to reducing erosion and modifying surface flow to reduce peak runoff and extend summer flow. Attempts to reduce erosion and modify the magnitude and timing of surface flow begin with the restoration of headwater meadows, which is the current focus of the FRCRM.

EVOLUTION OF THE FRCRM RESTORATION STRATEGY

The FRCRM restoration effort has evolved from implementing demonstration projects located mid-level in the watershed that treat sediment supply problems, to restoring the water and sediment retention and release functions in headwater reaches. After more than a decade of experience, FRCRM partners have determined that the primary channel characteristic impacting restoration goals is the disconnection of the channel from its historic functional floodplain. This channel/floodplain disconnection is pervasive throughout the upper watershed meadows and valleys due to past land management practices. Reconnecting degraded streams to their floodplain has become is a major area of emphasis for the FRCRM. Though there is no "cookbook" as to when and where a given technique or combination of techniques should be used, the FRCRM has successfully used a geomorphic approach on alluvial meadow projects. One such project, Cottonwood Creek/ Big Flat Meadow, is described in the FRCRM Fact Sheet below.

The restoration approach has also evolved from a project level focus to a broader watershed scale. Historical and current watershed effects are taken into consideration in the design and implementation process via watershed analysis. In addition, emphasis has shifted from a "project-of-opportunity" approach to a strategic approach that provides for long-term watershed maintenance in the highest priority areas at the right time. The FRCRM is also seeking to build bridges and form partnerships with academia, to apply better science to restoration projects, and better understand watershed processes.

ACTIVITIES IN 1999

Current FRCRM activities include headwater meadow rewatering projects, road rehabilitation and obliteration, testing alternative land management practices, biotechnical revegetation, watershed analysis, and preparation of technical papers that document results. The FRCRM has also formed several partnerships with academic institutions to propose and carry out research projects that improve our understanding of watershed function and its relationship to restoration.

The FRCRM is also implementing a two-year pilot watershed monitoring for the upper Feather River. The program is funded through a Clean Water Act 319 (h) grant. The purpose of the program is to identify and evaluate long-term trends in watershed condition resulting cumulatively from restoration activities, land management changes and natural processes. A series of permanent sampling stations and stream reference reaches have been established in 33 watershed locations, and data collection will be conducted through June 2000. The monitoring strategy is based on the Stream Condition Inventory (SCI) protocol developed by the US Forest Service, which includes geomorphologic, biologic and chemical parameters. The program will be integrated with ongoing Feather River monitoring activities conducted by federal and state agencies and the Quincy Library Group. A GIS data management system that is compatible with the Plumas National Forest system has been developed to facilitate data storage, analysis and sharing. Data will be made available via the FRCRM website in year 2000.

Two geomorphic stream restoration projects are being implemented over the next two years in the Indian Creek watershed. The project is funded by a Proposition 204 grant and seeks to reduce meadow erosion, improve fish and wildlife habitat, while maintaining a productive ranch operation. A geomorphic approach will be used to reconnect Ward Creek with its floodplain and repair the entrenched channel that now drains the meadow. Initial monitoring of similar CRM meadow projects indicates the potential for functional meadow floodplains to attenuate floods and increase summer baseflows through groundwater storage. A conversion of vegetation from less desirable dry site annuals and forbs to perennial moist meadow grasses is also anticipated.

FRCRM ACTIVITIES, 1985 TO PRESENT

Erosion Costs

Much of the Feather River watershed has been affected by 140 years of intensive human influence. Fifty percent of the land is publicly owned and administered by the U.S. Forest Service's Plumas National Forest. Open valleys within the national forest contain the majority of the county's 20,000 population and most of the arable and grazed lands. Mining, grazing, timber harvesting, wildfire, and railroad and road construction and maintenance have all contributed to down cutting and widening of the Feather's tributary streams.

At least 60% of the EBNFFR watershed has been affected by erosion (USFS, 1992). Many meadows and upland areas have lost the equivalent of 6 to 12 inches of top soil since settlement. Accelerated erosion has caused meadows to drain, lowering the water table and allowing sagebrush to invade areas once dominated by moisture loving species such as sedges and willows. Vegetation change and lower water quality caused by erosion have reduced the productivity and diversity of fish and wildlife populations in the Feather River and tributary streams. These changes together affect tourism and recreation (one of Plumas County's main economic bases); reduce the amount and value of forage available for livestock grazing; and increase flood damage to streamside property owners.

Accelerated erosion also affects the distant consumers of natural resources from the Feather River watershed. Sediments produced by erosion travel downstream to Pacific Gas and Electric's (PG&E) hydroelectric system on the Feather River. The Natural Resources Conservation Service estimates that 1.1 million tons of sediment per year are delivered to PG&E's Rock Creek Reservoir at the downstream end of the EBNFFR, and that nearly 80% is caused by "accelerated" human erosion (SCS 1989). Rock Creek and Cresta Reservoirs have been reduced by accumulated sediment to 46% and 56% of original capacity, respectively. This loss of water holding capacity eventually affects the 600,000 consumers of PG&E's electrical power and the 20 million water users served by the State Water Project (SWP), for which the EBNFFR supplies 25% of the total water.

Donna Lindquist

Feather River CRM Origins

In 1984, PG&E began an effort to develop a long-term plan to manage sediment at their Rock Creek Reservoir. It began surveying the watershed and tracking sediment to better understand where erosion problems are concentrated. PG&E initiated a series of meetings with the government agencies responsible for controlling erosion upstream from their dams, including the Army Corps of Engineers, the California Department of Fish & Game, the Natural Resources Conservation Service (formerly the Soil Conservation Service), the Plumas National Forest, and Plumas County. As the agencies met to discuss the erosion problem, they agreed that attempts to control erosion needed to be cooperative, involving many agencies both from the upper watershed and downstream areas.

In 1985, the agencies organized themselves into a Coordinated Resource Management (CRM) group. Participating organizations signed a Memorandum of Understanding (MOU) setting up goals and guidelines for working together on erosion control projects across the entire watershed. The MOU articulates the CRM goals of:

- Identifying erosion sources,
- Coordinating between public and private land owners,
- Implementing erosion control projects where practical,
- Ensuring project cost effectiveness for contributors, and
- Developing a cooperative regional erosion control plan.

Coordinated Resource Management promotes an integrated approach to watershed restoration. Actions taken by government agencies are coordinated around specific on the ground projects. The contributions of each agency or individual are leveraged by the contributions of others, increasing cost effectiveness. This enhances the credibility, visibility, and funding opportunities for the group.

There are currently over 30 active CRM groups operating at the local level in California. The Feather River CRM was developed to encourage local initiative and participation in resource management and to coordinate requests for Federal and State technical and financial assistance. Representatives of 21 organizations including resource management and regulatory agencies, local technical experts, local government officials, and an association of private land owners serve on the steering committee, project technical assistance committees, and management committees. In addition to the agencies that have signed the MOU, numerous other county agencies, private consultants, community groups, and students have worked together on CRM projects.

CRM structure and process

The Feather River CRM is composed of three main committees; the Executive Committee, Management Committee, and Steering Committee. In addition, four sub-committees, with open membership, exist as arms of the Management Committee. They are the Projects, Finance, Design, and Monitoring sub-committees.

The Executive Committee is responsible for policy guidance and dispute resolution, and support in the political arena. The Management Committee is responsible for administration of projects. The Steering Committee is composed of representatives from each contributing organization who review program status, approve new projects, and interact with landowners.

Ideally, all affected parties necessary to implement long-term, comprehensive solutions are involved at the beginning of the project planning process. Since participation in the CRM is voluntary, participants must recognize that the value of benefits they will receive outweigh the value of their contributions. All decision-making on project prioritization is based on consensus, with ultimate control resting in the hands of the land owners. Public and private landowners should take the lead on projects on their own lands, developing project goals and providing land use history information. All participants, including technical experts, investors and regulators need to agree to attempt to achieve shared goals, assist in securing required project permits, and use monitoring to document the success or failure of the restoration project.

Once a project is endorsed, a Technical Advisory Committee (TAC) of resource specialists, landowners, interest groups and anyone with a specific interest in the site is formed to evaluate the site and design the project. Implementation and funding requests are coordinated by Plumas Corporation, the local non-profit economic development corporation.

CRM accomplishments

Since the Feather River CRM's inception in 1985, CRM members have cooperated on over 40 watershed projects including studies and assessments, resource management plans, on-the-ground restoration projects, and educational efforts. Intensive water quality and channel condition inventories have been conducted on approximately 40% of the EBNFFR watershed. Projects have included restoration of an urban stream and an abandoned mine, meadow re-watering, check dam building, and installation of fish ladders. At least 14.5 miles of stream and 4,000 riparian acres have been treated, producing 94 full or part time jobs. Stream bank stabilization, decreases in erosion, and increases in water table height and wildlife habitat quality have been documented for some projects.

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One focus of the CRM has been to test innovative restoration techniques using demonstration projects. As with any innovative technology, projects have not always been as successful as hoped. However, lessons learned from less successful projects can be used to add to the knowledge base of the locally emerging field of watershed restoration.

CRM activities have also led to the establishment of the first community college watershed management technician program in California at Feather River College in Quincy. Local high school students are also gaining scientific knowledge and skills through their involvement in project monitoring.

CRM funding

Over $4,100,000 has been spent on CRM restoration and research projects since 1985. CRM projects have been carried out using a mix of funds and in-kind contributions from PG&E, landowners, government agencies, state and federal grant programs, and private donors. Pacific Gas & Electric company has invested approximately $1.1 million in erosion control projects since 1984 and anticipates that over the long-term, erosion control projects may reduce waterborne sediment delivery to Rock Creek and Cresta Reservoirs by as much as 50%. (Harrison and Lindquist, 1995).

Future goals

In addition to continuing with implementation of new restoration projects, the CRM has proposed a strategy for addressing erosion problems throughout the entire watershed. The erosion control strategy, developed in 1994, is a systematic method for coordinating resource restoration and management on a sub-watershed, watershed, and landscape scale (USFS 1994). The strategy identifies streams with high erosion potential and prioritizes areas where erosion control measures would be best implemented. The CRM has been actively seeking new funding mechanisms to implement this restoration strategy. One source being explored is reinvestment in the watershed by downstream water users, with user fees or some other funding mechanism. Until such a broad-reaching plan can be implemented, Feather River CRM members plan to continue working to control erosion in the Feather River watershed on a project by project basis.

FEATHER RIVER CRM FOCUS

- The CRM works on the cumulative watershed effects on water quality, desertification, and reductions in biodiversity on public and private lands.
- The CRM uses education, innovative restoration technology, and demonstration projects to encourage cooperation and participation, rather than regulatory approaches.
- The CRM realizes that enlightened self-interest and a long-term investment horizon are necessary attributes for achieving solutions that are economically and environmentally sustainable.
- The CRM works on solutions which can be monitored for ecosystem recovery using ecological function and succession criteria.
- The CRM works on solutions where monitoring will influence long-term sustainable management strategies for restored resources.

MEMBERS OF THE FEATHER RIVER CRM

FEDERAL:

Plumas National Forest, USFS/USDA
Natural Resource Conservation Service, USDA
North Cal-Neva Resource Conservation and Development Area
U.S. Army Corps of Engineers
Farm Services Agency, USDA
U.S. Fish and Wildlife Service

STATE OF CALIFORNIA:

Department of Fish and Game
Department of Forestry & Fire Protection
Department of Parks and Recreation
Department of Transportation
Department of Water Resources
Regional Water Quality Control Board, Central Valley
University of California Cooperative Extension

LOCAL GOVERNMENT:

Plumas County
Plumas County Community Development Commission
Plumas Unified School District
Feather River Resource Conservation District
Feather River College

PRIVATE:

Pacific Gas & Electric
Salmonid Restoration Federation
Plumas Corporation

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Project Director: Michael De Lasaux, Natural Resources Advisor
Educational Outreach Coordinator: Susie Kocher, Program Representative

Donna Lindquist

Plenary Session

Boise River 2000: Dynamics, Challenges and Successes of Implementing a Management Plan

Organizer: *Bill Clayton, Chair, Boise River 2000; President, Boise River Flood Control District, #10, P.O. Box 46, Star, Idaho 83669*

BOISE RIVER 2000

Panelists: *Gary Spackman, Idaho Department of Water Resources, Boise, Idaho*
Robbin Finch, City of Boise, Idaho
Clair Bowman, Ada Planning Association, Boise, Idaho
Marti Bridges, Idaho Rivers United, Boise, Idaho
Peter Goodwin, Eco-Hydraulics Research Group, University of Idaho, Boise, Idaho
Nelson Matthews, Trust for Public Lands, Trust for Public Lands, San Francisco, California

Abstract. *Not so long ago, the Boise River flowed freely through this valley. Only in the nineteenth century did a few settlers and wanderers begin putting roots along the river, establishing homesteads, farms and the first traces of Treasure Valley's communities. Today these communities have grown into cities — and, as more and more people place demands on and seek the benefits of the area, a complicated mixture of problems facing the river (including safety, irrigation, floods, pollution, and environmental protection) has arisen in our day-to-day lives. Now is the time to create a real plan for the Boise River. Recently, Boise River 2000 was established as a nonprofit organization with the goal of supporting development of a long-range plan which incorporates opinions and ideas of the river's many users and admirers. Its specific purpose is to bring together the communities of the Treasure Valley in order to solve the problems facing the river today. We are asking communities-minded individuals and organizations like yours to contribute expertise and/or funds to help formulate a future for the Boise River.*[2]

BOISE RIVER NEEDS A COORDINATED OPERATION PLAN

Sandbags. Tree breaches levee at Eagle Island. Floating picnic tables. Flooded houses and basements. Closed Greenbelt. Downed trees on bridges. High water where experts did not expect. FEMA announces funds available for planning.

Scenes and situations such as these have been common around the Boise River this year (1998) and last. However, with some planning, high river flows would not present so many problems.

Although we all enjoy and benefit from the river, the Treasure Valley still lacks a comprehensive and coherent long-range plan for the Boise River. Despite enjoying the river in many different ways and using it as a symbol for the playful and lucrative Boise River Festival, we have not committed ourselves to developing a long-term plan for the health of the river and the community.

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

[2]*Adapted from comments originally printed in Speakers' Corner, The Idaho Statesman, June 12, 1998*

As a result of failing to plan, past decisions about the river have been made largely on a case-by-case basis by multiple agencies, outside of the framework of any general plan and often as an emergency response. Little comprehensive planning and participation exist.

As one example, for the past few years, Flood Control District No. 10 has held public meetings to discuss the removal of gravel and a few trees near Eagle Island that potentially could cause flooding during high flows. These public meetings were attended primarily by people opposed to the activities.

In contrast, during a recent period of high water and increased river attention, elected officials and representatives of local, state and national agencies met to discuss the current river situation and proposed responses to the flooding.
Although both of the meetings addressed potential solutions to flooding challenges, each meeting was attended by an entirely different group of people with different interests and agendas. The point is not that we cannot have different ideas, rather that there needs to be a coordinated effort with a long-term perspective.

Creating a long-term plan for the river is certainly not an easy task. The issues are complicated. We must incorporate diverse and often conflicting concerns about flooding, recreation, irrigation, fishing, conservation and development.

For example, while removing a particular log from the river may reduce localized flooding, this action may also eliminate overhead cover for fish. Similarly, later in the spring, slowly reducing the river's flow over a period of several weeks instead of several hours would reduce streambank erosion problems and improve establishment of native tree species, such as black cottonwood. However, these adjustments to the dam operations also require additional water that no group is willing to make available at this time. Healthy decisions for the community and the river require a coordinated framework for evaluating the relative costs and benefits associated with our river management decisions.

Now is the time to create a real plan for the Boise River. In other parts of the West, such plans exist and work successfully. There are currently efforts under way for the Boise River that address specific areas and concerns, including a plan to be presented by the Idaho Water Resource Board to the Legislature in 2001 and a water quality study being conducted by the state Division of Environmental Quality. However, there is no single coordinated effort that ties together all of the projects under way now and in the future.

Recently, Boise River 2000 was established as a nonprofit organization with the goal of supporting development of a long-range plan which incorporates opinions and ideas of the river's many users and admirers. Many agree that the Boise River is the most valuable asset we have in the Treasure Valley. It is why the settlers stopped here, why the farmers have fertile crops, and why many of us enjoy calling this area our home. However, as leaders and residents we must stop "floating along" comfortably during the low water and then reacting frantically when the river rises. We must make the Boise River a priority. Whether we live along the river or on the outer reaches of Ada and Canyon counties, we must take the proactive steps and start paddling and planning for the future of the Boise River.

KEYNOTE ADDRESS

CUMULATIVE WATERSHED EFFECTS RESEARCH NEEDS FOR FORESTED WATERSHEDS IN THE 21ST CENTURY[1]

Walter F. Megahan[2]

Abstract. *Key cumulative effects research needs dealing with forest watersheds include natural variability in watershed characteristics and in downstream responses, sediment routing, and effects of disturbance on streamflow. Important information needs relating to natural variability include better descriptions of spatial variability and a broader perspective on temporal variability. Large regional differences in landslide types and streamflow rates are used to illustrate the need for studies of spatial variability. Justification for increased research on temporal variability is based on recent studies documenting long-term (1000s of years) sediment supplies from mountain watersheds in Idaho averaging about an order of magnitude greater than present day (10s of years) sediment data indicate. Additional studies in western Oregon show that mountain channels exhibit a natural succession from energy limited (aggraded) to supply limited (degraded) conditions, with accompanying changes in aquatic habitat conditions. Important components of sediment routing research include delivery of landslide material to channels, downslope sediment from roads to channels, and downstream routing of bedload sediments in channels. Evaluation of the effects of disturbance on streamflow should include the effects of forest management and wildfire on all levels of streamflow, and the accompanying erosional and sedimentation response of channels and aquatic ecosystems. Physically-based, distributed models need to be developed and improved to predict effects of disturbance on streamflow and channel changes.*

INTRODUCTION

I feel that futuring exercises are somewhat presumptuous, but given the observation by Charles Kettering that "The future is where I expect to spend the rest of my life", some futuring might be appropriate. It's even more appropriate when one considers that the 21st century is less than a year away. At the risk of showing my biases, I will attempt to provide my perceptions of some important cumulative watershed effects (CWE) research needs dealing with sedimentation, channel responses, and streamflow on forested watersheds in the Pacific Northwest. Given present concerns about the effects of forest management on aquatic organisms and on downstream flooding, such research is particularly important at present, and will no doubt continue to be well into the next century. I do this knowing full well that present day perspectives of research needs can be greatly influenced by future developments such as technological advances or legislation. Consider, for example, how CWE research has changed with the development of computers, remote sensing capabilities, and digital terrain modeling and with the enactment of the Clean Water Act and the Endangered Species Act. Given those caveats, my assessment of several important CWE research needs are given by general subject areas including "natural variability", sediment routing, and hydrologic processes.

NATURAL VARIABILITY

Terms such as "natural", "natural variability", or "natural range of variability" are often used with little understanding of what is really involved. Most of us are necessarily provincial when defining these terms because we base our definition on our own experience. In addition, our desire for what we would like "natural" to be often influences our definition. Most people have little understanding of how much variability actually exists in nature. Yet, it is important to gain some understanding of the nature and extent of natural variability because, rightly or wrongly, the "natural" state is often used as a benchmark against which we evaluate risks of human-caused disturbance. An understanding of natural variability also helps us avoid broad-scale "one size fits all" management and/or regulatory decisions that ignore natural variability. For purposes of this discussion, I will define natural variability as watershed ecosystem response in the absence of modern human disturbance. Factors influencing natural variability include spatial and temporal components.

Spatial variability — Spatial or regional variability is characterized by differences in geology, climate, landform, soils, and vegetation. We are all aware that broad-scale regional and local variability exists because of differences in site characteristics. However, as technical specialists familiar with local conditions, we tend to be much more

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*
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attuned to local variability rather than regional. Yet broad-scale regional differences can be important. Regional differences are best characterized by geologic, climatic, and landform conditions because these are the most independent elements of the ecosystem. Soils and vegetation are, for the most part, manifest elements derived from basic geology, climate, and landform. Two important elements, landslides and streamflow, provide examples of the need for assessing spatial differences. Landslide risks are greatly increased in locations such as western Washington where large, deep-seated landslides occur in glacial deposits in addition to the shallow landslides common in all steep mountainous lands. Geologic formations elsewhere, such as the Franciscan Formation in northern California, provide similar deep-seated landslide risks. Regional climatic variability provides similar differences in hydrologic response. For example, 25-year return interval peak flows average about an order of magnitude greater for small forested watersheds on the west side of the Cascade Mountains compared to similar watersheds east of the Cascades. Differences in low flows are even greater, ranging from one to two orders of magnitude greater on streams west of the Cascades compared to streams to the east. Knowledge of such flow differences is important not just in terms of streamflow rates, but also in terms of sediment transport, aquatic organisms, and the magnitude and duration of effects of watershed disturbances. The point is that broad scale regional and local variability does occur, and a concerted research and development effort is needed to characterize this variability. Such an effort will help to avoid extrapolating research results, management decisions, and regulations to locations and situations where they are not appropriate.

<u>Temporal variability</u> — Temporal variability is more difficult to perceive because available data and our work experience includes only a small window to long-term climate trends and natural disturbances such as wildfires, weather extremes, insect attacks and earthquakes. I will illustrate research needs to better define two key management issues affecting downstream cumulative effects, sediment supply and channel sediment routing.

<u>Sediment supply</u> — Numerous publications document that sediment supply (sediment yields) can vary considerably from year to year in response to varying weather conditions, and that episodic climatic events can increase sediment yields. However, long-term sediment yield data are limited to decades at best on undisturbed watersheds. For the last several years, NCASI and the National Science Foundation have co-equally supported a study to evaluate the utility of cosmogenic isotope (nuclide) tracers for determining long-term sediment yields on mountain watersheds. Principal investigator for the study is Dr. James Kirchner from the University of California at Berkeley. This project compares cosmogenic isotope measurements of sediment yield (which are averaged over a time scale on the order of 10,000 years) with direct measurements of present day sediment yield by sediment trapping or sediment gauging methods (which are averaged over time scales of years to decades). The intent of the study is to help clarify and quantify mechanisms controlling sediment yield over different time scales.

Cosmogenic isotopes are produced inside mineral grains by cosmic rays bombarding the Earth's surface. Cosmic ray intensity decreases rapidly with depth, so cosmogenic isotopes are concentrated within the upper 1 or 2 meters of the surface. The concentration of cosmogenic isotopes in minerals indirectly records the length of time that those minerals have been close enough to the Earth's surface to be exposed to cosmic rays, and thus provides a measure of their average erosion rate. A recent study (Granger, Kirchner, and Finkel, 1996) showed that cosmogenic nuclide concentrations in stream sediments accurately reflect the area-averaged long-term erosion rates of whole watersheds even if different parts of the watershed are eroding at different rates. Because cosmogenic nuclide concentrations reflect average erosion rates over thousand-year time scales, they are insensitive to recent changes in erosion rates. This makes them particularly useful for estimating long-term "background" rates of erosion as a benchmark for evaluating present day sediment yields.

With the help of scientists from the U.S. Forest Service, Rocky Mountain Experiment Station and from technical specialists from several National Forests, sediment data were compiled from 34 essentially undisturbed, forested watersheds in Idaho ranging in size from 0.2 to 35,000 km2. Length of record for the watersheds ranged from 4 to 79 years and averaged about 20 years. Sediment samples were collected from each watershed and analyzed for cosmogenic nuclide content to determine long-term average sediment yield. Part of the long-term measurement includes the effects of solution erosion, which is not reflected in the short-term data. After accounting for probable solution erosion, the long term sediment rates still exceed short-term rates by a factor of about 10 (Kirchner et al, 1998).

The Idaho watersheds had little or no glaciation, nor can the large differences between long- and short-term sediment rates be explained by climatic differences between Pleistocene and current climatic conditions. Apparently, long-term erosion rates are driven by relatively rare episodic events that overshadow the short-term conditions we like to think of as "natural". Episodic events are caused by large storms often coupled with natural disturbances, especially wildfire, and result in very large sediment yields that can have major impacts on channel systems. A number of examples of episodic events have occurred in Idaho in recent years. Large storm events occurred in 1965-66 and again in 1996-97 and caused widespread landslide and channel damage in many Idaho watersheds (Megahan et al, 1979; McClelland et al., 1997). Intense wildfires on the Boise National Forest in Idaho have caused massive erosion and sedimentation damage in headwater basins (USDA Forest Service, Boise National Forest, 1996; Pacific Watershed Associates, 1998).

Channel Responses — Benda and Dunne (1997a,b) developed a stochastic model to evaluate the effects of large storm events and natural wildfire on long-term (3000 years) landslide erosion and resulting channel responses in the North Fork of the Smith River basin in western Oregon. Their studies show a natural succession of channel conditions ranging from sediment rich aggraded situations following wildfire and associated landslides to sediment deficient conditions over time frames of several years to many decades as accumulated sediments are carried downstream. The magnitude and duration of aggradation effects varies with the location in the drainage system. Steeper third order channels show large accumulation of bed sediments that are removed relative rapidly. Sediment deposits in fifth order channels tend to be slightly shallower and last longer. In sixth order channels sediment deposits are considerably less and exhibit less variability. Channels in the study area are most commonly sediment supply limited, as characterized by large bed elements and a bedrock floor (average thickness of bed material <0.3m). Such conditions occur 93 percent of the time in third order streams, 70 percent of the time in fifth order streams, and 77 percent of the time in sixth order streams (Table 1). Aggraded channel conditions with a gravel bed (average thickness of bed material >1m) occur only 4 percent of the time in third order channels, 15 percent of the time in fifth order channels and not at all in sixth order channels. Intermediate sediment supply conditions characterized by mixed channel morphology (average thickness of bed material between 0.2m and 1.0m) occurs 3, 15, and 23 percent of the time in third, fifth, and sixth order channels, respectively. However, it is important to note that the sediments in the sixth order channel occur as thin gravel sheets with an average depth of <0.4m, making such channels almost continually supply limited. Benda and Dunne's work shows that channel systems naturally evolve from energy limited to supply limited conditions over a period of years to decades, and that the supply limited condition is the most probable state at all locations within the drainage system. They also describe a natural succession of aquatic habitat conditions associated with the transition from energy to supply limited conditions. Benda and Dunne (1997a,b) did not include the effects of large woody debris (LWD) in their model. Although LWD would increase the occurrence of localized bed sediment accumulations, the overall trends demonstrated by Benda and Dunne would be likely to remain the same.

In summary, recent work by Kirchner et al. (1998) utilizing radionuclide tracers in sediments demonstrates that long-term erosion rates from undisturbed, forested watersheds in Idaho average about ten times greater than present day erosion rates. The researchers conclude that the large average erosion rates are the result of episodic events such as wildfire and large storms that are not reflected in the present day erosion rate data. Observations of extensive landsliding and flooding from large storms in Idaho during 1996-97 as well as massive surface erosion and channel damage from intense wildfires in southern Idaho in 1996 demonstrate widespread examples of extreme erosion from episodic events. Complementary modeling studies illustrate episodic sediment supply from landslides associated with large storm events and wildfire in mountain watersheds in Oregon (Benda and Dunne 1997a) and exhibit a natural succession from energy limited to supply limited conditions in channels following episodic erosion events. They further illustrate that supply limited conditions are the most probable state for mountain channels (Benda and Dunne, 1997b). These studies clearly illustrate that the natural range of variability of forested watersheds and channels draining therefrom is far greater than the generally accepted norm for "undisturbed" forested watersheds. It is obvious that research is needed to better define natural variability in sediment production and channels and what such variability means to aquatic ecosystems and other beneficial uses within watersheds in relation to land management activities.

SEDIMENT ROUTING

Sedimentation cumulative effects are dependent on two geomorphic processes, sediment supply (erosion) and the routing of sediments to and down channels. I will consider three aspects of sediment routing: 1) delivery of landslide material to streams; 2) delivery of sediments resulting from surface erosion on sites disturbed by forest management practices; and 3) downstream routing of bedload sediments in stream channels.

Delivery of landslide material — Landslides constitute a major source of sediments during episodic storm events. For example, McClellend et al. (1996) reported a total of 700,000 cubic yards of landslide erosion during the 1995-96 storm events on the Clearwater National Forest in Idaho. About 57 percent of this amount reached streams. In an earlier study on the same forest, Megahan et al. (1978) found a total of 716,000 cubic yards of landslide erosion during the three-year period from 1974 to 1976. Sediment delivery for the three years ranged from 11 to 32 percent. Empirical data of this sort suggests a wide variation in landslide sediment delivery to streams. Given the episodic nature of the events and the large sediment

TABLE 1.

Modeled frequency of occurrence of streambed sediment conditions for channels of varying sizes in the coast range of Oregon (derived from Benda and Dunne, 1997b).

Channel order, watershed size	Sediment limited, bedrock floored[1]	Intermediate sediment supply, mixed morphology[2]	Channel aggradation, gravel bed[3]
3rd order, $3 km^2$	93	3	4
5th order, $25 km^2$	70	15	15
6th order, $125 km^2$	77	23	0

[1] Sediment deposits average about 0.1m deep and the bottom is characterized by bedrock, boulders and some cobbles with limited pool development.

[2] In 3rd and 5th order streams, sediment deposits average about 0.5m deep with a predominant bottom particle size of gravels and an average pool depth of 0.3m. The 6th order channel is characterized by bedrock with discontinuous lenses of sediment consisting of mostly gravels averaging <0.4m deep.

[3] Sediment deposits average about 1.8m deep and are often capped by smaller particle sizes; pools average 0.7m deep but many pools are dry during low flow conditions.

volumes involved, it is important to develop methods to predict landslide delivery based on site characteristics. Such a capability could then be coupled with landslide risk models such as those developed by Montgomery and Dietrich, (1994) and Pack et al. (1998) to define the risk of sediment supply from landslides. Limited work has been done to relate landslide delivery to site conditions. For example, Benda and Cundy (1990) developed landslide delivery rules in confined mountain channels based on slope gradient and tributary junction angle, and Ward (1994) described landslide runout models based on slope gradient. Such work needs to be expanded to other kinds of landslides and sites, especially for landslides associated with the construction of forest roads.

Downslope delivery from surface erosion on roads — Surface erosion on forest roads is the major source of sediment from forest management activities. To illustrate, Megahan and Kidd (1972) found that logging activities increased surface erosion by a factor of 0.6 as compared to roads, which increased surface erosion by a factor of 220. Aside from direct entry of sediment at channel crossings, Megahan and Ketcheson (1996) show that sediment travel below roads is by far the greatest at points of concentrated flow such as at cross drains, and developed models for granitic sediment transport distance below roads based on hillslope and road characteristics. They also developed a dimensionless relationship to define how much sediment travels how far. Such work makes it possible to develop sediment yield prediction models that allow forest managers to change road location and design and to alter downslope sediment storage conditions in order to regulate the introduction of road sediments to channels. Empirical studies of this type need to be expanded to other locations. Process models such as WEPP (Tysdal et al. 1997) hold promise for predicting downslope sediment travel distance and amounts but must be validated against actual field data.

Downstream routing of channel sediments — The impacts of sediment on channels and aquatic organisms depend on how rapidly sediment particles are transported downstream from the point of supply. Clay, silts, and small sands are generally transported rapidly out of the system as suspended load (Whiting et al., in press). However, larger sand, gravel, cobble, and boulder particles in the streambed are carried downstream as bedload. Rate of bedload movement depends on local channel characteristics, sediment particle size, rate of sediment supply from above, and energy available for transport (streamflow rate). The channel sediment storage and routing model described by Benda and Dunne (1997b) relies on a simple, empirically-based, sediment wave translation relationship for routing sediments downstream. Empirical studies on coastal streams (Madej and Ozaki, 1996; Miller and Benda, in press) document downstream propagation of sediment waves. Other studies (Cui et al. 1998) suggest that introduced sediment deposits tend to dissipate in place rather than move downstream as a coherent wave. Process models are available (Federal Energy Regulatory Commission, 1988) for predicting downstream sediment movement, but all require very detailed, site specific input data and have various other limitations, making them impractical for application to forest land management problems. More research is needed both in the laboratory (flume studies) and in the field to develop and/or test practical models for downstream routing of bedload sediments through the hierarchy of channel conditions occurring on mountainous, forested watersheds. This work must be accompanied by studies to assess the effects of large woody debris on sediment routing throughout the drainage system. Finally, additional studies are needed to develop procedures to evaluate how aquatic organisms respond to changing channel morphology as sediments travel downstream.

EFFECTS OF DISTURBANCE ON STREAMFLOW

Early studies of the effects of timber management on streamflow focused on changes in annual water yield. However, the present day scope of concern has expanded to all flow levels and to effects of other kinds of natural disturbances, especially wildfire.

Effects of forest management on streamflow rates — Numerous case studies of the effects of forest cutting on streamflow document increases in water yield primarily in response to reduced evapotranspiration. However, relatively little work has been done to document how peak flows change, and those that are available send mixed signals. For example, increased peak flows have been found in some locations whereas no changes or decreases have been found elsewhere. The problem is epitomized by two recent papers evaluating the effects of timber cutting and associated road construction on peak flows on large and small watersheds in Oregon. Jones and Grant (1996) reported large increases in peak flows (50% in small basins and 100% in large basins), suggested that such increases occur for all sizes of flow events, and concluded that forest road construction is the major mechanism responsible for such changes. Thomas and Megahan (1998), utilizing the same data sets, concluded that flow responses on large watersheds were inconclusive, that peak flows were increased up to 90 percent on small watersheds but effects were inversely proportional to flow event size and time after disturbance, and that there was little evidence to suggest that roads were a major mechanism causing increased flows. Part of the disparity in results is due to the nature and interpretation of the statistical analyses used. However, lack of knowledge about basic hydrologic processes also contributes.

Thomas and Megahan (1998) suggest a plan of research to deal with the question of forest management on peak flows. They recommend:

> *"First, we need more studies to better understand runoff processes from forested slopes with and without cutting and road effects with an emphasis on the role of macropores. Process studies should be nested within carefully controlled small watershed studies to integrate watershed scale responses. At the small water shed scale, it should be possible to "switch" road effects on and off by alternating between outsloped and insloped road drainage design over time. Insloping maximizes delivery of road runoff to streams whereas outsloping delivers runoff to the slope below the road and thus minimizes effects. Process studies of this sort, should be coupled with the development and validation of physically based, distributed hydrologic models in order to forecast the effects of forest cutting and roading activities on a given watershed. Recent advances in such simulation model development (La Marche and Lettenmaier, 1998) are a start in this direction. Once such models have been validated against measured results from controlled small watershed studies of roading and cutting effects, they should provide a viable means for evaluating timber harvest effects in large basins as well."*

Concerns about the effect of forest management on streamflow go beyond peak flows. Because of increased concerns about water pollution and aquatic ecosystem responses, effects of forest practices on other flow levels including base flows and flow duration will also become more important. In order to deal with these issues, process studies to better identify and predict forest management effects on runoff mechanisms including subsurface flow (both macropore and Darcian flow), surface runoff, and groundwater flow are needed. This work must be incorporated into existing and developing physically-based, distributed runoff models to account for all the runoff processes and variability in site conditions influencing all levels of streamflow. Finally, studies are needed to determine the geomorphic and ecologic significance of changes in streamflow, including soil erosion and sediment routing.

<u>Effects of wildfire on streamflow</u> — Intense wildfire can have a greater impact on streamflow than any other type of forest disturbance. Peak flows ranging from 4240 to 5380 $ft^3sec^{-1}mi^{-2}$ were recorded on three small watersheds (size range 0.39 to 2.25 mi^2) above Boise, Idaho following intense wildfires in 1959. Extreme floods for other selected Idaho streams with unburned but larger watersheds show peaks less than 60 $ft^3sec^{-1}mi^{-2}$ (Crippen and Bue, 1977; Thomas, 1963). A review of data from small, undisturbed forest watersheds in Idaho similar in size to the burned watersheds also showed no peak flows greater than 60 $ft^3sec^{-1}mi^{-2}$ (Mosko et al., 1990). These data suggest that intense wildfire can increase extreme flood peaks by a factor of up to 100 times, far in excess of studies showing increases in flood peaks following forest management practices ranging from none to <1.0. In spite of the extreme effects of intense wildfire on peak flows, there has been limited research to document the effects of wildfire on runoff and streamflow. Such work is especially germane given the present debate about ecosystem management in relation to wildfire on forest lands (Agee, 1993).

Wildfire increases the occurrence of water repellent soils which, in turn, increase surface runoff. Studies should include the areal extent, depth, and duration of water repellency in relation to burn intensity for varying site conditions and should be accompanied by measurements of surface runoff in relation to site conditions and burn intensity. Additional studies are needed to document and predict soil erosion accompanying overland flow and the resulting downstream sediment transport. Research methods should include onsite plot studies as well as watershed-scale post mortem assessment of existing wildfire-flood-erosion episodes to assess scale effects. Given the magnitude of potential flow increases from wildfire, it is imperative to adapt physically-based, distributed models to include the effects of fire-induced water repellency and the associated overland flow and to account for the short duration routing of flood runoff. Model development should include components to evaluate soil and channel erosion and downstream routing of sediments. Addition work is needed to document the immediate and long term geomorphic and ecologic effects of wildfire floods on the channel system.

CONCLUSIONS

Important research needs for Pacific Northwest forested watersheds in the 21st century include studies of natural variability, sediment routing, and evaluation of the effects of watershed disturbances on streamflow. Evaluation of natural variability must include assessments of spatial variability as well as temporal variability because of large regional differences in geology, climate, and landform and because recent studies document much greater temporal variability in sediment yields and stream channel conditions than currently available data sets would suggest. Sediment routing studies must include methods to predict delivery of landslide and surface eroded materials to streams as well as the development of practical methods to predict downstream routing of bedload sediments. Finally, studies are needed to better assess effects of forest management practices and wildfire on all levels of streamflow and the accompanying geomorphic and ecologic responses. This can be accomplished by process and watershed-scale studies conducted under the umbrella of distributed, physically based models designed to predict streamflow changes from forest disturbances.

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Plenary Session

ROADS IN WATERSHEDS

Organizer: *James L. Clayton*
USDA Forest Service
Boise, Idaho

FOREST SERVICE ROAD AND ROADLESS POLICIES OPTIONS AND RATIONALE[1]

Christopher A. Wood[2]

Abstract. *Forest roads provide millions of Americans access to national forests and grasslands. Roads contribute to economic well-being by facilitating the removal of commodities, as well as management access for such activities as fire-fighting. However, roads can also cause and accelerate erosion and landslides, allow the dispersal of exotic species, and fragment wildlife and fish habitat. This paper examines the USDA Forest Service's recent proposal to suspend temporarily road construction in most roadless areas of the national forest system and to develop a new, comprehensive long-term forest road policy.*

ROAD AND ROADLESS POLICIES

I'm flattered to be here and honored to be among so many that have done so much for conservation over the years.

I was asked to speak about the policy aspects of roadless areas, forest roads, and the Forest Service road policy. Many may agree or disagree with our new approach to managing forest roads and protecting roadless areas. All, however, would agree to one indisputable fact. Few natural resource issues have proven as controversial and intractable for the Forest Service in recent years as management of our forest road system. For example:

- Several years ago, we came within a single vote of losing most of our funding for forest roads in the House of Representatives.
- Road-related issues have become a nursery-ground for "riders" during the congressional appropriations process.
- Recent studies from western forests document and confirm the causal relationship among some roads and timber harvest and landslides and erosion.
- Citizens are increasingly dissatisfied with our management of forest roads – as evidenced by unhappiness over road closures due to declining maintenance or erosion. Conversely, others protest new road construction – especially in roadless areas – literally placing themselves between bulldozer and forest.

Let's talk about roadless areas for a moment. We know they are both socially and ecologically important. Research developed and collected through the Columbia River Basin Science Assessment documents their values most clearly. For example:

- Over 80% of the subbasins with the *highest* forest integrity possess more than 50% roadless areas and wilderness. Conversely, of those subbasins with the *lowest* forest integrity about 90% were comprised of less than 25% roadless areas and wilderness.
- Only 7% of the degraded watersheds in the basin are found within roadless areas.
- About 60% of the best aquatic habitats were found in roadless or very low road density areas.
- The Science Assessment stated that "the existence of unroaded areas is far the most valuable output from FS and BLM administered lands in the basin today, and will continue to be so in the year 2045."

These findings are amplified by the report of the Forest Ecosystem Management Assessment Team (FEMAT) in the Pacific Northwest. The FEMAT team noted that unroaded areas are very important for fish. For example,

- Of the 162 healthiest watersheds in the study area, 48-70% were within wilderness or very low road density areas.

This is noteworthy because gravity works cheap and never takes a day off. Aquatic species are the ultimate indicator of the overall health of the land. How we manage our lands is reflected in the quality of our water and the abundance of our species.

The irony is much of the political and social heat over the roads debate has focused on roadless areas, many, if not most at high elevation areas with steep slopes. These are often the *least productive* aquatic habitats. The *most* productive are along the valley bottoms and larger rivers. Yet, it is the roadless areas that get all of the attention.

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The fact that the best remaining habitats are found within what is historically the least productive part of the landscape speaks to the importance of roadless areas as strongholds to which we need to anchor our restoration of the more productive parts of our watersheds.

Yet, if we ever intend to reconnect the fragmented pieces of the landscape to a healthy whole, *we must look to restore the areas that are already roaded.* Unfortunately, talking about roads is like talking about the crazy aunt in the attic. Long forgotten, and when she shows up our hope is that if we just ignore her, maybe she'll simply go away.

The Forest Service maintains a road network of over 372,000 miles. Approximately 75% of these roads are *not* accessible by typical passenger cars. An additional estimated 60,000 miles of "uninventoried" roads also exist. I call these "ghost roads." Our engineers admonish and inform me they are actually unauthorized, nonsystem travel-ways. Whatever term you choose, our management issues are serious.

- We only receive funding to maintain about 25% of our forest roads to the safety and environmental standards to which they were designed.

- In addition, a whopping $8.5 billion – that's billion with a "b" – backlog on road reconstruction needs – culvert replacement, bridge work, and so on – remains unmet.

What's going on here? Forest roads are an essential part of the transportation system in many rural parts of the country. They help to meet recreation demands on national forests and grasslands. I hike and drive regularly on forest roads to fish on the George Washington and Monagahela National Forests back east.

- Forest roads provide economic opportunities by facilitating the removal of commodities from forests providing jobs and revenue.

- Forest roads provide access to conduct needed management such as fire fighting.

The benefits of forest roads are many. The problem is, so too are the ecological impacts on our watersheds. Building a new road requires a short-term outlay of cash. Funding its maintenance over time entails a long-term financial commitment. The failure to maintain the forest road system has the effect of limiting public access and causing tremendous environmental damage.

There are few more irreparable marks we can leave on the land than to build a road. Among other deleterious impacts, improperly located, designed or maintained roads contribute to:

- erosion,

- wildlife and fish habitat fragmentation,

- degradation of water quality,

- the loss of wild places, and

- dispersal of exotic species.

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The policy question that Chief Dombeck and the Forest Service address is straightforward. How can the Forest Service provide public access while minimizing, indeed reversing, the damage caused by forest roads? We'll talk about that more in a minute but first we should recognize how we found ourselves in this position, lest at some point in the future we be condemned to repeat the past.

Fewer than 10 years ago, we were harvesting about 12 billion board feet of timber a year from national forests. Since the 1960s, we've probably financed about 80-90% of our roads to facilitate the removal of wood fiber from national forests. The more timber we harvested, the more money we could bring into the organization to build and maintain more roads.

But it did not end with roads. Timber harvest was a means to an end. The more timber we harvested, the more money we could bring into the organization to fund restoration projects, biologist's salaries, recreation projects, and so on. Timber money helped to essentially finance much of our organization. So long as the timber flowed, everything worked out fine. Yet, as you know, for good reasons, the timber slowed.

Today, we harvest about 3.5 billion board feet of timber – about a 70% reduction from a decade ago. We build far fewer miles of new road and, also, maintain far fewer roads to standard. Today, the values that most people associate with national forests are:

- clean water,

- outdoor recreation,

- wildlife and fish habitat,

- wildness,

- ecologically sustainable development, and

- leaving choices for future generations.

The point is that we need to transform our view of forests as a warehouse of *outputs* to one that considers the positive *outcomes* of forest management. Outcomes that take shape through such values as water quality, healthy and diverse forests, productive and stable soils, and so on. Only by first ensuring the health, diversity, and productivity of our public lands can we ever hope to provide other goods and services to people and communities.

We need to make investments in the land. Investments that may not yield immediate benefits in terms of economic profit or short-term gain but whose long-term benefits are measured through healthy, diverse and productive forests.

BACK TO ROADS

For all of these reasons, the Forest Service proposed suspending temporarily the construction of new roads in roadless areas. This was based on the ecological reasons mentioned above as well as what I call the Rule of Holes. When you find yourself in a deep ditch, the best thing to do is put down the shovel.

Due to our unmet needs and our existing backlog, it is a matter of basic accountability that we slow new road construction – particularly in sensitive roadless areas – until we can better manage our existing road system. With that in mind, we identified four preliminary objectives for our long-term road policy.

- First, more carefully consider decisions to build new roads.
- Second, eliminate old, unneeded, or unauthorized roads.
- Third, upgrade and maintain roads that are important to public access, as necessary.
- Fourth, develop new and dependable funding for forest road management.

Our proposal to suspend temporarily road construction in roadless areas is not only a scientific issue; it is a matter of *accountability*. How can we responsibly make irreversible decisions about such valuable areas when we cannot afford to take care of the road system we already have?

Our intent is to provide local managers with the scientific tools they need to work with local people to make more informed local decisions about when, and if, to construct new roads. This is our obligation as resource professionals and our duty to the American taxpayer.

Christopher A. Wood

CONSEQUENCES OF ROADS FOR AQUATIC BIOTA[1]

Christopher A. Frissell[2]

Abstract. *Roads cause manifold direct and systemic ecological impacts whose cause and effect linkages can be difficult to partition. The direct consequences of roads often cannot be segregated from the effects of intended and unintended changes in land use that roads support. Among the recognized biological changes associated with incursion of roads into wildlands are 1) declines in native species sensitive to sedimentation, warming, habitat instability, and other environmental changes caused by disruption of watershed processes, 2) fragmentation of existing populations by physical barriers or by mortality caused by road traffic; 3) expanded human access that increases legal and illegal harvest pressure, 4) compounded incidence of invasions or introduction of non-native plants, pathogens, fishes, and other biota. Many of these effects are irreversible, others can be fully reversed only after roads are physically removed and the landscape restored. Of course the specific effects of any road vary according to its characteristics, history, and ecological setting, and some roads are clearly more damaging than others. However, when the full range of impacts of roads on biotic integrity of terrestrial and aquatic ecosystems is accounted for, most mitigation measures commonly prescribed for roads appear marginally effective or even counterproductive. This underscores the importance for biological conservation of 1) of avoiding construction of new roads in presently roadless or sparsely-roaded areas, and 2) restoration treatments of existing road networks that are carefully tailored to benefit both terrestrial and aquatic biota, not just at a single site but across the landscape.*

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ROADS IN FOREST WATERSHEDS - ASSESSING EFFECTS FROM A LANDSCAPE PERSPECTIVE[1]

Fred Swanson[2], Julia Jones[3], Beverley Wemple[4], and Kai Snyder[5]

Abstract. *Road networks have a great variety of effects on forest watersheds. The type, strength, and location of these effects depends strongly on the interactions of roads with forest landscape structure and topography. A landscape perspective provides a useful basis for examining effects of roads on terrestrial and stream ecosystems. A landscape approach considers lateral effects of roads on adjacent terrestrial systems and also effects of road networks on stream and riparian networks. From a watershed viewpoint, it is useful to emphasize movement of water, sediment, woody debris, debris slides, and debris flows—all of which follow gravitational flow paths. Results of an assessment of erosion features resulting from a major flood reveal the great influence of hillslope position on the effects of roads on sediment routing. An assessment of the watershed effects of roads can incorporate: (1) broad-scale consideration of road and stream network densities—areas with high densities of both networks have highest potential for interaction, (2) propagation of road effects through stream and riparian networks, and (3) site-scale analysis of potential problems.*

INTRODUCTION

We offer some landscape perspectives for examining effects of roads on terrestrial and stream ecosystems. Historically, much of the analysis of effects of roads on ecosystems has been based on site-level investigations or views restricted to road rights-of-way. More recently, particularly in Europe, effects of roads have been addressed with a landscape approach emphasizing the zone of influences of roads extending laterally into terrestrial ecosystems. This approach can be supplemented by consideration of effects of road networks on stream and riparian networks.

In this paper, we consider how landscape structure affects road influences on terrestrial and stream systems. In the realm of stream networks, we emphasize movement of water, sediment, and debris flows—all of which follow gravitational flow paths and are major issues in watershed management. Road-related movement of exotic plants into forest landscapes is also considered briefly to offer an example of transfer processes that do not follow gravitational paths. We close with some consideration of implications for assessment procedures.

These landscape perspectives derive in part from a series of studies centered on the H.J. Andrews Experimental Forest in the Oregon Cascades directed at understanding effects of roads on surface (Jones and Grant, 1996; Wemple et al., 1996; Wemple, 1999) and subsurface (Wemple and Dutton, in progress) water fluxes, road-associated erosion and deposition events during the February 1996 flood (Swanson et al., 1998; Wemple, 1999), debris flows (Wallenstein and Swanson, 1996, in prep.; Snyder, in prep.), and exotic plants (Parendes, 1997). We also draw on findings of European research. A general treatment of interactions of road networks and stream networks is presented in Jones et al. (submitted).

LANDSCAPE STRUCTURES AND FLOWS

For our purposes, it is convenient to view landscapes as composed of interacting vegetation patchworks and networks of streams, riparian zones, and ridges (Swanson et al., 1997). Patchworks are created by substrate contrasts and disturbance processes, such as fire, windthrow, and patch clearcutting. Segments of networks may penetrate or border vegetation patches. Networks function as pathways for accumulation or dispersal of materials (such as stream water), animals (such as game using ridge trails or anadromous fish migrating through stream systems), and plant parts (such as seeds dispersed on the gentle breezes of cool air drainage patterns).

Energy, organisms, and material may move between patches and network segments (Fig. 1). Traffic along roads, for example, may be vectors for movement of exotic plant species into forest landscapes; and under favorable circumstances, those organisms may move into adjacent areas, such as clearcut patches (path 2 in Fig. 1). Runoff and associated sediment from recently disturbed patches of vegetation may move downslope to be intercepted by a road (a patch to network interaction, as show by path 1 in Fig. 1) and then routed down a ditch to the native stream network (a network-network interaction, path 3 in Fig. 1).

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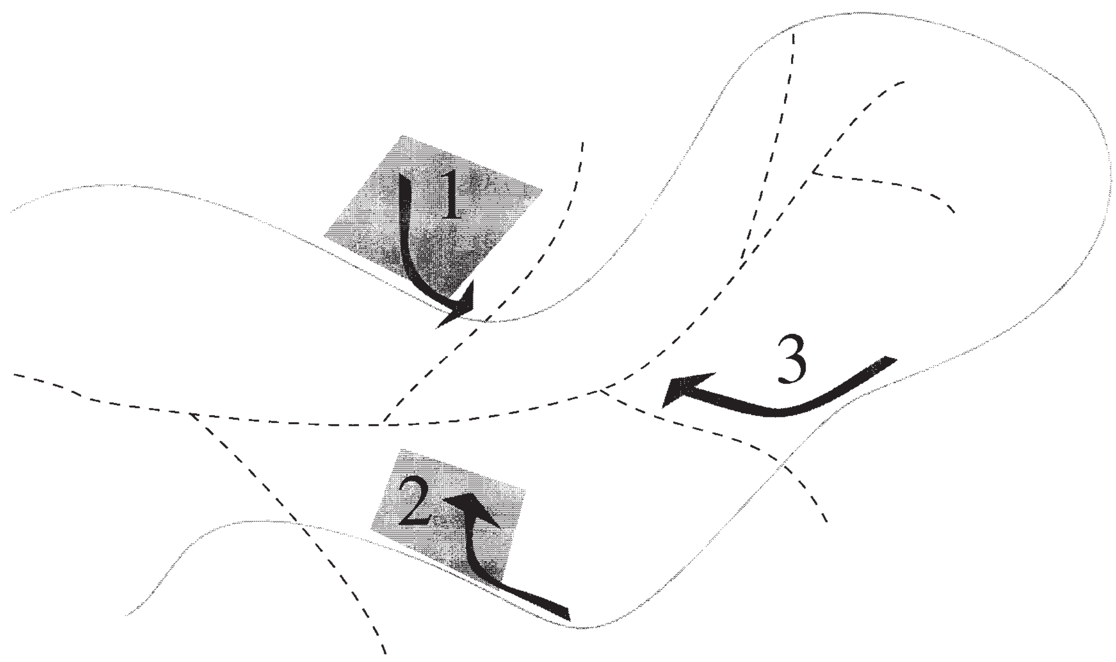

Figure 1. Types of network-patchwork interactions involving roads. Material (e.g., water, sediment), organisms (including propagules), and energy can move from vegetation patches to segments of a road network (1), from road segments to vegetation patches (2), and between road and stream networks (3).

Much of the literature in landscape ecology has been by terrestrial ecologists who tend to see the world as composed of vegetation patches which serve as habitat for wildlife. Studies of the significance of the network structure of streams and roads are uncommon. Many management issues in forested watersheds, especially issues concerning roads, involve understanding of interactions of patchwork and network structures within the landscape.

ZONES OF ROAD INFLUENCE

Ecologists have identified a wide array of road influences on adjacent ecosystems, which can be broadly grouped into the roles of roads as sources (e.g., traffic noise and road dust), sinks (e.g., road kill which results in reduced population size in the vicinity of roads), corridors (e.g., paths for movement of some species along roads), and barriers (e.g., impeding movement of some species, but without necessarily functioning as a sink in terms of mortality) (Fig. 2). Roads form exotic networks in landscapes that exert a variety of influences on the neighboring, native, terrestrial ecosystem patchworks and intersecting stream networks. Roads may have exotic functions in landscapes in the senses of involving non-native, compacted surfaces and drainage structures that carry water across hillslopes and potentially from one natural drainage basin to another. Vehicle traffic can alter the road itself (such as producing fine sediment and dust), directly affect neighboring ecosystems (such as through effects of traffic noise on animal movement), and introduce exotic species into a landscape—species that may eventually affect adjacent terrestrial and aquatic systems.

The influences of roads on terrestrial and stream ecosystems is contingent on the processes perpetrating the influence and the terrain over which that influence is exercised. Topographic factors, such as the hillslope position of a road segment, can strongly affect the type and extent of road effects. Steep hillslopes, for example, can extend road influences greater distances downslope from a road, but a nearby ridge may limit the lateral extent of a road influence. Approaches to examining road effects on ecosystems differ between terrestrial patchworks and stream/riparian networks.

Interaction of Road Networks and Terrestrial Systems

The source and sink types of influences of roads on terrestrial ecosystems have distinctive zones of influence that vary in width, depending on many factors. For example, the impact of road kill on populations of organisms in neighboring areas will depend on dimensions of the home range and on traffic intensity, among many factors.

Complexities of road networks as corridors for dispersal and for interaction with adjacent vegetation patches are represented by recent work on exotic plants in a Cascade Mountain forest landscapes (Parendes, 1997). Some exotic species are widely distributed along forest road networks, while others exhibit a quite spotty distribution. There may be some interaction of the road-side environment (seedbed) and the adjacent vegetation patch (light environment) that determines favorable sites for establishment. However, statistical relations are weak, especially for species with very limited dispersal capabilities; hence, chance plays a big role in determining their distribution. Most exotic species have limited potential for dispersal into adjacent vegetation patches in the Cascade study site, but elsewhere, problem species seem to spread inexorably. These cases include gorse and Port Orford cedar root rot in southern, coastal Oregon, and Himalaya blackberry more widely.

A common approach to assessing the extent of the road influence on a landscape (Fig. 3) has been to multiply road length (or density) by the width of the zone of influence and divide by the overall area of analysis. This gives a measure of the percent of landscape area affected by roads. Using this approach, Richard Forman (Harvard University, personal communication) has estimated that 25% of the United States is influenced by roads. At the present time, such analyses are subject to debate, but it is striking to note that the geographic extent of road impact may be an order of magnitude greater than the extent of the road network itself.

Interaction of Road and Stream Networks

The geometry and interaction of different networks, such as roads and streams, have received scant attention in published studies. We expect that steep hillslopes create a tendency for high densities of road-stream intersections and, hence, interactions (Fig. 4). The gradient of roads is constrained by maximum grades for safe vehicle movement (commonly <10%), so on steep slopes, roads have high angles of intersection with streams, thus favoring high densities of road-stream intersections. Along valley floors of larger channels, roads typically parallel the main stream (Fig. 4) and may encroach on the floodplain and even the channel area itself. These valley floor roads also intersect tributary streams at high angles of intersection (Fig. 4). We hypothesize that these geometric relations strongly influence the types of road-stream interactions in various parts of a landscape.

The dominant effects of road networks on stream and riparian networks involve alteration of routing of water, water-born chemicals, sediment, and mass movements to and through native stream networks. Recent work in the Oregon Cascades provides examples of some of these interactions. Wemple et al. (1996) observed that segments of roads can act as extensions of the native stream network, thus increasing the drainage density of watersheds, which may alter the ability of watersheds to produce peak

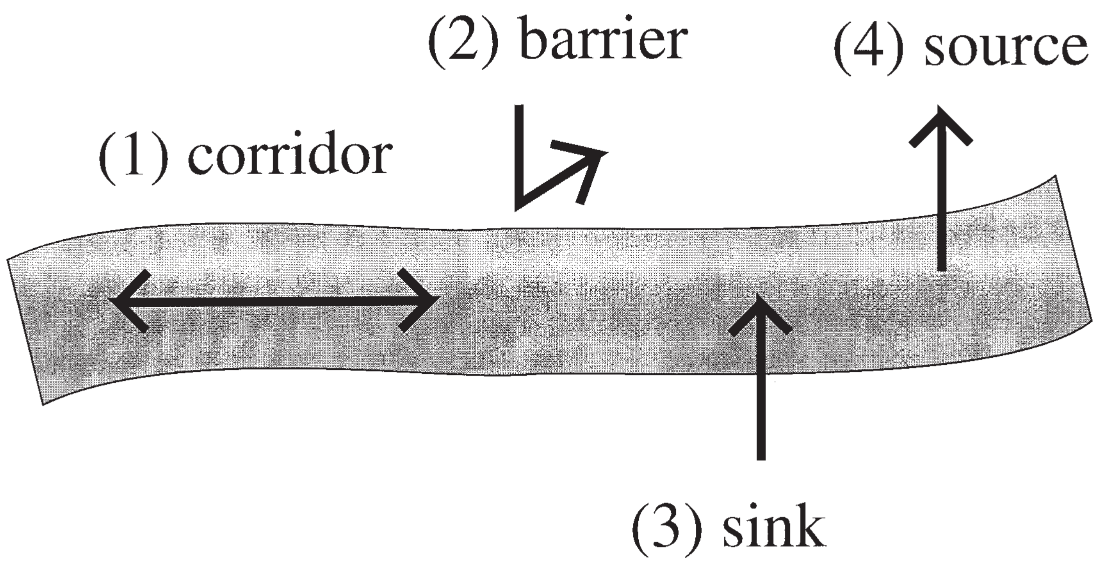

Figure 2. Roads can function as sources, sinks, corridors, or barriers for movement of material, organisms, and energy through landscapes.

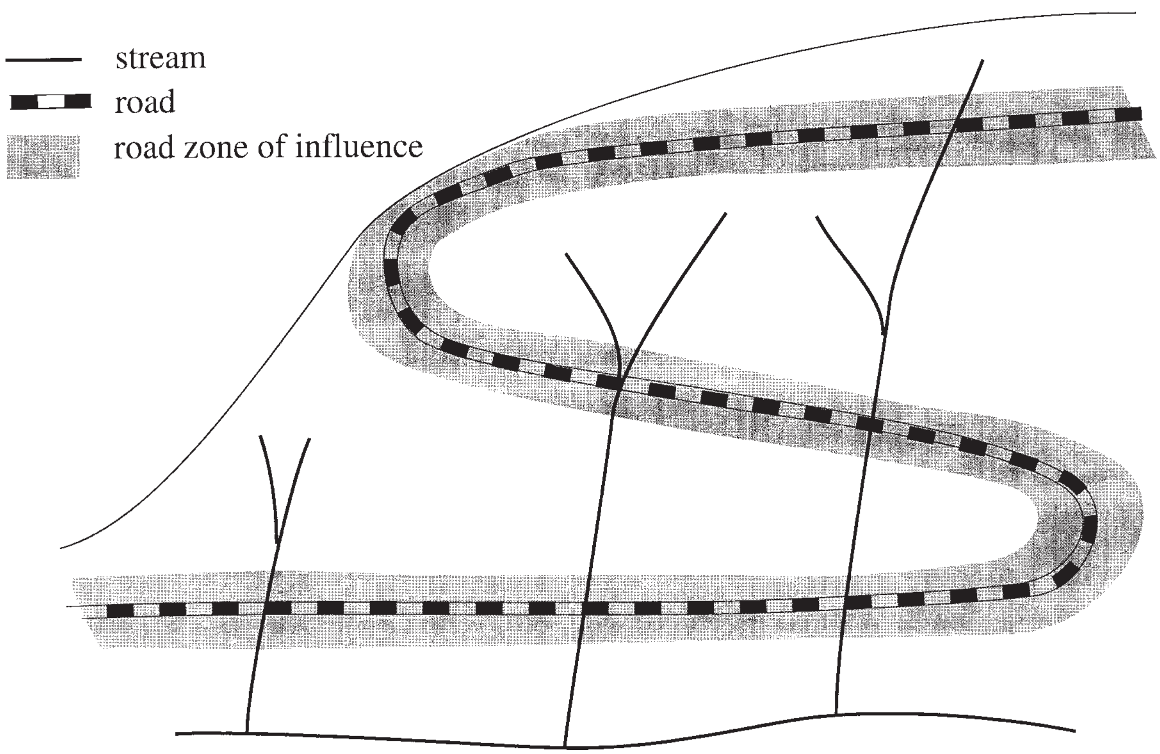

Figure 3. Zones of road influence on terrestrial ecosystems can be represented in the simplest way as a zone extending laterally from the road. A simple estimate of extent of road influence in area of road influence zone divided by area of landscape or watershed assessed.

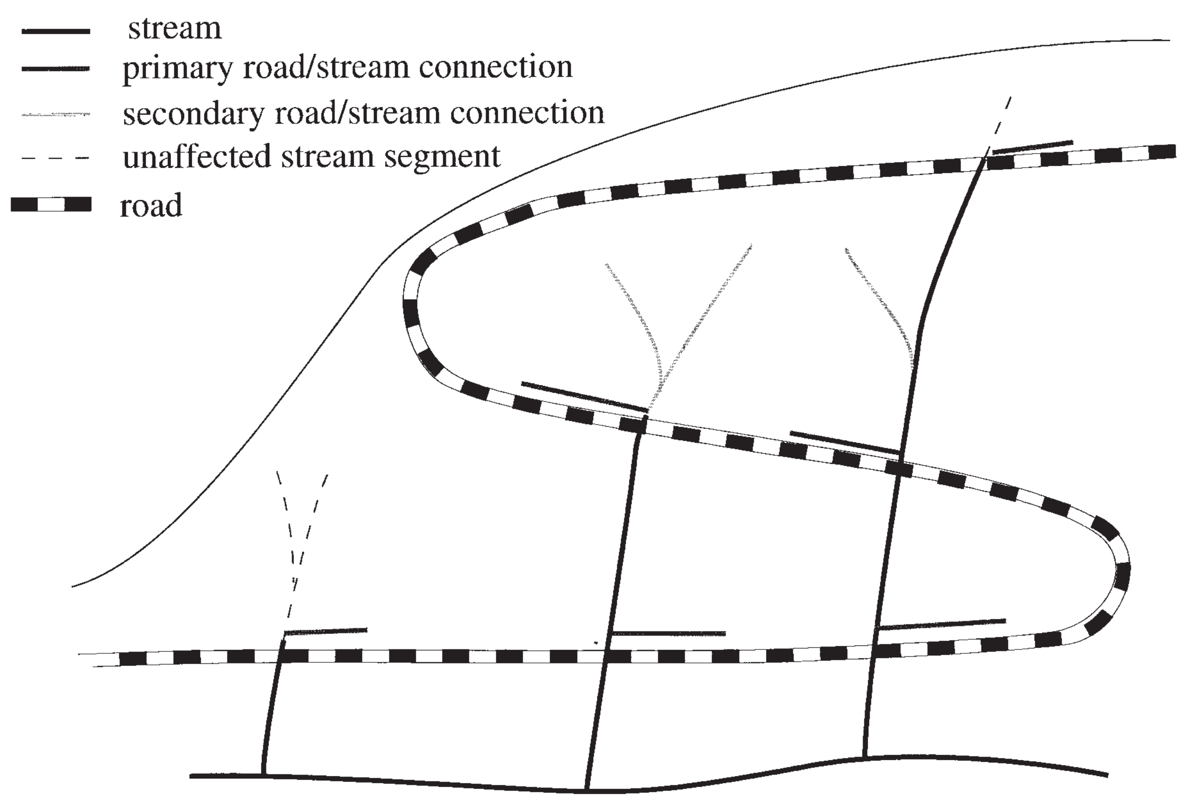

Figure 4. Effects of roads on stream and riparian networks include road ditches serving as extensions of the stream network and effects of streams and associated materials (e.g., sediment) on road segments encountered along the flowpath. The extent of stream network potentially affected by road influences can be expressed in terms of direct and potential influences and in terms of percent of network length affected and in terms of percent extension of drainage network density.

flow events (Jones and Grant, 1996). Wemple (1999) conducted an inventory of more than 100 erosion/deposition features affecting the road system in the upper Blue River drainage in the Cascades. She distinguished seven types of features involving both mass movement (e.g., cutslope or hillslope slides, debris flows from upstream areas) and fluvial processes (e.g., gullying resulting from culvert blockage by excess bedload). The density of the various types of road-related, erosion/deposition features varied strongly with hillslope position. Road segments within 100 m of ridges had a relatively low frequency of such features, and they all originated from the road as fillslope failures. Road segments on steep hillslopes below the near-ridge zone experienced high frequency and diversity of erosion/deposition features, and these roads were net sources of sediment to downslope and downstream areas. Valley floor roads located on floodplains, terraces, and alluvial fans had 10 times the frequency of features of the near-ridge roads and were net storage sites (sinks) for sediment coming from up slope areas.

Analysis of the extent of road influence on stream and riparian networks is most usefully expressed in terms of the percent of stream network length affected in various ways by road influences (Fig. 4). For example, segments of roads draining to native streams (Fig. 4) increase drainage density by definable amounts (Wemple et al., 1996). It is useful to stratify the analysis by stream order, since some processes may be restricted to certain orders. Debris flows, for example, are largely limited to first- through third-order streams where they may affect more than 10% of channel length. However, a much higher percentage of larger channels in debris-flow-affected watersheds experience elevated sediment loads from these headwater events (Jones et al., submitted).

We hypothesize that the greatest effects of roads on stream and riparian networks occur where the densities (length of network per unit of overall landscape area) of both types of network are highest (Fig. 5). For some processes, the degree of this interaction might be indexed by the density of road-stream intersections per unit of watershed area. One important area of future work is to assess stream geomorphic and ecologic characteristics of watershed areas representing different parts of the field of road and stream densities (Fig. 5) to see if a response surface can be defined for key watershed conditions. We could also try to identify thresholds of stream and road densities above which undesired conditions tend to develop. Such analyses need to be placed in the context of capabilities of particular watersheds to show responses, such as their inherent hydrologic and sediment production regimes.

MANAGEMENT IMPLICATIONS

These observations and general concepts suggest several implications for assessment and mitigation of road effects in watersheds. We have been impressed by the strong influence of slope position on the watershed functions of roads in terms of water and sediment routing during floods. Analysis of how hillslope position affects road erosion and damage during floods, such as Wemple s (1999) work, gives a strong quantitative basis for estimating the payoff from modifying roads with objectives of reducing maintenance costs or restoring watershed conditions. Such quantitative analysis of road effects on water and sediment routing can target specific functions of roads, such as sediment or debris flow sources and sinks. Engineering design can then be set in both site and larger watershed contexts.

Assessment of road influences on stream ecosystems can be approached at a series of related scales. At a broad scale, the highest levels of interaction between road and stream networks can be expected to occur where both types of networks occur in high densities. Geographic Information Systems procedures can be used to map and analyze the density of each network type in units of length per unit area and to identify areas with high densities of both types. At a finer scale, the patterns of road-stream intersections can be examined through the stream network to identify areas of high densities of intersections where management action might reduce adverse effects. At the finest scale, traditional, site-level analysis is employed to identify problems and site-scale engineering solutions, but can be set in the contexts of hillslope position, network location, and likelihood of various processes affecting the site or being translated to downslope and downstream areas.

In summary, we believe that a landscape perspective is essential to assessing and managing effects of roads in landscapes and in stream and riparian networks. A landscape approach complements the more traditional approach of assessing roads by simply considering the road right-of-way. Roads are an integral, multi-faceted part of any watershed they occupy.

ACKNOWLEDGMENTS

We appreciate the contributions of many colleagues, including Gordon Grant, Laurie Parendes, Matt Wallenstein, Julie Donald, and Mike Furniss. This work was supported in part by the USDA Forest Service, Pacific Northwest Research Station; the National Science Foundation (BSR-90-11663 and DEB 96-32921 for the H.J. Andrews Experimental Forest Long-Term Ecological Research Program); and the Bureau of Land Management (task order #H952-A1-0101-19).

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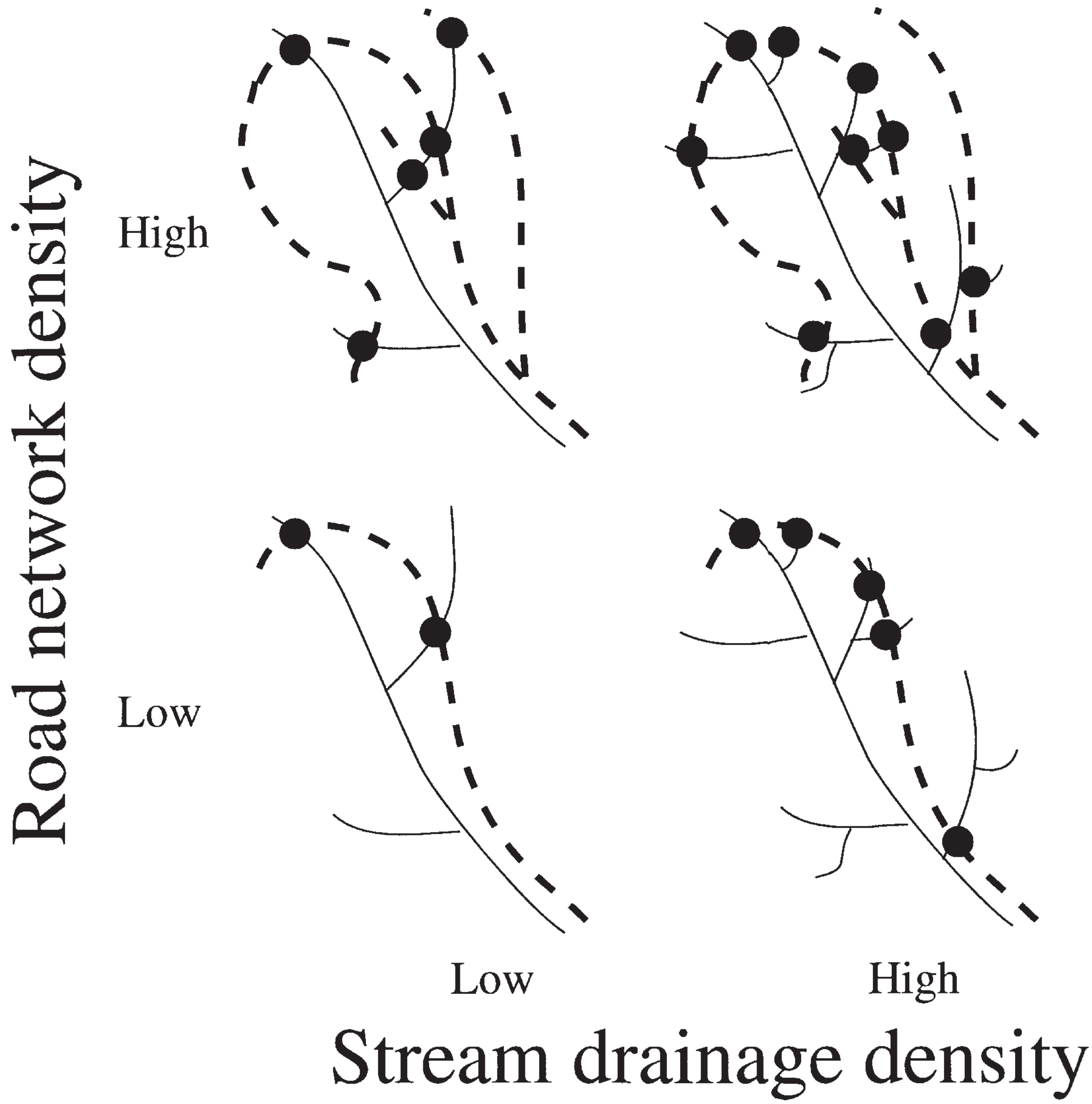

Figure 5. Schematic examples of road (dashed line) and stream (solid line) networks of high and low densities, showing highest density of road-stream intersections (dots) and, therefore, potential interactions in watersheds with high densities of both roads and streams.

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Plenary Session

SCIENCE, SENSE, AND NONSCIENCE

Organizer: *Terry Kaplan-Henry*
USDA Forest Service
Porterville, California

NON-STRUCTURAL FLOOD MANAGEMENT AND RESTORATION: CONCEPT VERSES CONCRETE[1]

Jeffrey Mount[2]

Abstract. *Since the Mississippi River floods of 1993 and the floods of 1997 in the West and Midwest, there has been an increasing emphasis on multi-objective flood plain management and the development of so-called non-structural flood damage reduction measures. Depending upon design, scope and objective, these measures appear to offer the greatest single opportunity for large-scale restoration of ecosystem health and function within lowland areas of degraded watersheds. Despite the logical connection between flood management and restoration there are three general issues that dog these efforts. First, institutional inertia and the 100-year flood plain approach to land use planning are powerful disincentives for restoration. Second, the flood memory half-life is shorter than the period needed to develop project scopes and funding. This often leads to political entropy and loss of opportunity. Third, the "fixit-syndrome" of the restoration community tends to limit the long-term success of restoration efforts. Rather than focusing on improving watershed function, most restoration efforts focus on imposing an idealized channel and riparian configuration that is based on one-size-fits-all classification schemes. The most constructive approach to restoration in lowland reaches is to allow channel and riparian systems the time and, most importantly, the space to develop a configuration that is adapted to changing watershed conditions.*

> *"ten thousand river commissions, with the mines of the world at their back, cannot tame that law less stream, cannot curb it or confine it, cannot say to it 'Go Here' or 'Go There', and make it obey; cannot save a shore which it has sentenced; cannot bar its path with an obstruction which it will not tear down, dance over and laugh at. But a discreet man will not put these things into spoken words;"*
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> Mark Twain, Life on the Mississippi

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[1]Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).
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DÉJÀ VU SHED[1]

Clay Brandow[2]

Abstract. *We don't make many mistakes; we just make the same ones over and over again, as Dave Rosgen is fond of saying. I couldn't agree more. Ever get that sinking feeling that working in watershed management is sometimes like déjà vu all over again (Yogi Berra)?" Here is a lighthearted look at the top ten situations that give me that sinking feeling - twenty years worth in twenty minutes.*

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[1]Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).

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FOREST HYDROMYTHOLOGY: MYTHS AND MISCONCEPTIONS ABOUT FORESTS, RAINFALL AND STREAMFLOW[1]

Robert Coats[2]

Abstract. *Myths and misconceptions about basic relationships of forest hydrology are firmly imbedded in popular culture, and have played an important role in American history. The notion that rainfall could be enhanced by planting crops, orchards and forests played an unfortunate role in the settlement of the arid west. The idea that timber harvest exacerbates flooding in large river basins played a more salutary role in the establishment of the Forest Reserve system. In efforts to develop simple indices and indicators of watershed health , foresters and hydrologists have sometimes promoted their own set of myths about forest hydrology. Generally the consequences of management programs based on mistaken ideas about watershed ecosystems have not been disastrous; an exception was the program to remove woody debris from streams in north coastal California. The history of misconceptions about forest hydrology suggests that 1) we should be very cautious in applying experience gained in one region to problems in another; 2) we should avoid the use of simple indices and formulas to solve complex management problems; 3) we should not embark on stream "improvement" programs without first analyzing the fluvial system from a geomorphic and ecological perspective; 4) we should be wary of hydrologic dogma.*

INTRODUCTION

Every hydrologist occasionally encounters popular myths and misconceptions about basic principles of hydrology. The idea that a peachwood stick may be used to locate groundwater, or that trees promote the flow of springs by wicking water up from the water table, is usually met with a bemused smile and perhaps a patient explanation of how the things really work. In efforts to develop quantitative tools for land management, however, hydrologists have sometimes developed their own myths and misconceptions. The purpose of this paper is to discuss some recent and historic myths and misconceptions, and to draw some lessons that may help us in our search for better tools for watershed management.

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The word myth has a number of definitions. The one used here is: a notion based more on tradition or convenience than on fact; a received idea (Morris, 1980).

VEGETATION AND RAINFALL: RAIN FOLLOWS THE PLOW

By the 1870s, the coastal areas of the U.S. were largely settled. The remaining frontier lay on the short-grass prairie and high plains, from which the buffalo and Native Americans had been recently exterminated or relocated . Hungry for land and encouraged by high grain prices, the high rainfall years of the 1870s, and Federal land policies better suited to a humid region, settlers flocked to the high plains west of the 100th meridian. John Wesley Powell and other foresighted scientists argued that the region was too arid to support family farms of 160 acres each, and to sustain non-irrigated grain crops (see Stegner, 1953). They were vociferously opposed by a powerful coalition of land speculators, railroad barons and politicians, who promoted the "garden-myth of the west" (Smith, 1947). According to this idea, the planting of crops, orchards and forests would cause rainfall to increase, allowing the region to ultimately grow to support a population 200,000,000. It was one Charles Dana Wilbur, a developer and speculator, who coined the slogan "rain follows the plow" (Stegner, 1953). The lush conditions of the 1870s seemed to support the myth, for as settlement increased, streamflow was seen to increase. But as Powell had warned, drought returned, lasting from 1886 into the 1890s. The conditions were eloquently described by Hamlin Garland, who wrote:

> *"There was no escape: east, west, north, south, July, August, September, the sun burned into the brain, the barrenness and loneliness and ugliness ate at man and woman alike, but at woman most"*.

The myth took a serious hit, but not before it had done, in Wallace Stegner's words "incalculable damage to western agricultural resources by encouraging grain farming where it never should have been attempted."

The idea that forests enhance rainfall was so firmly embedded in the consciousness of Americans that the advocates of the scientific study of forest influences and forest hydrology attacked the idea only with great caution. In a detailed review of the relationship between forests and rainfall, B.E. Fernow (1893) wrote:

> *"The facts at hand do not prove, with entire conviction, that forests increase rainfall...It is more probable that forests exist because of rainfall, rather than vice versa."*

We now know, especially from our recent experience in a year of a strong Nino, that precipitation in the western U.S. is strongly influenced by surface sea temperatures, by the path of the jet stream, and by local and regional topography. Not local vegetation, but forces on a global scale as well as local and regional topography determine the timing and amounts of precipitation we receive (Coghlin, 1984).

But not all of the world is like North America. In the Amazon Basin, evapotranspiration from the forest is an important source of water vapor for precipitation. Using a coupled numerical model of the global atmosphere and biosphere, Shukla et al. (1990) showed that deforestation in the Amazon basin may cause an increase in surface temperature, a decrease in both evaporation and precipitation, and an increase in the length of the dry season. The modeled changes are large enough for the authors to suggest that

> *" ...a complete and rapid destruction of the Amazon tropical forest could be irreversible. Changes in the region's hydrologic cycle and the disruption of complex plant-animal relations could be so profound that, once the tropical forests were destroyed, they might not be able to reestablish themselves."*

So while afforestation in North America will not enhance rainfall, deforestation in tropical South America may reduce it—another example of the folly of applying temperate zone experience to the tropics.

FORESTS AND STREAMFLOW

The effects of timber harvest on water yield and summer streamflow is by now an old story, going back to the first paired watershed study in the U.S. at Wagonwheel Gap, Colorado, in 1909. Bosch and Hewlett (1982) summarized the results of 94 catchment experiments worldwide; in no case was a reduction in vegetation associated with a reduction in water yield; tree removal generally increases water yield by reducing evapotranspiration loss. Least we get too confident about these relationships, however, Harr (1980) found that patch cutting of 25 percent of two small watersheds had no significant effect on water yield, and actually reduced summer low flow significantly, an effect attributed to a reduction in fog drip.

The mythology of forests, logging and streamflow is best developed, however, around the issue of the impacts of timber harvest and forest clearing on floods. The notion that extensive logging increases large floods in large river basins figured prominently in the creation of the Forest Reserve system, and the early advocates of forest conservation contributed to the mythology surrounding logging and flooding. This was due in part to a question about the constitutionality of federal ownership of forest lands, except for protection of navigable streams. As long as the forest reserves were needed to protect navigation, the constitutional question did not arise. Thus the Organic Act of 1897 provided that:

> *"...no national forest shall be established except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of the citizens of the United States"* (USDA Forest Service, 1974).

And the 1902 Forest Reserve Manual gave as the principal reasons for maintaining forests: 1) to furnish timber and 2) to regulate the flow of water (Kittredge, 1948).

From the late 1870s to the early 1940s, foresters (especially in the U.S. Forest Service) argued that forest cover played a major role in ameliorating regional floods in large river basins. Forest clearing was thought to be a major cause of large floods, and the solution, according to the Forest Service, was forest conservation and reforestation. Disastrous floods in the Ohio and Mississippi River Valleys focused public attention on the hydrologic role of forest cover, and provided an opportunity for the Forest Service to build support for expanding the National Forest system and reforestation programs (Shepard, 1928; Schiff, 1962).

Unfortunately, many of the foresters' claims about forests and floods were without strong scientific support. This weakness led to criticism from Hiram Chittenden (1909) of the Army Corps of Engineers and Willis Moore, Chief of U.S. Weather Bureau. Moore (1910) asserted that the runoff of rivers is not materially affected by any other factor than the precipitation. As late as 1937, W.G. Hoyt of the Geological Survey wrote:

> *"It is a sad commentary on the so-called scientific organization like the Forest Service that during its existence it has never published a report on the role played by vegetal cover on the hydrologic cycle which was in accord with well-established hydrologic principles. In the history of that organization the hydraulic engineer or hydrologist engaged on experiment relating to influence of vegetal cover on streamflow has*

been conspicuous by his absence." (cited in Schiff, 1962).

This controversy had the beneficial effect of stimulating experimentation and study on the relation between forests and streamflow. In 1910, the Forest Service and the Weather Bureau jointly began the world's first paired watershed study at Wagonwheel Gap, Colorado. This study produced useful information, but was beset by controversy and conflict between the Forest Service and Weather Bureau. The Forest Service came close to distorting the results to emphasize the role of forests in preventing floods (Schiff, 1962). It was not until the late 1930s, with the establishment of research programs such as those at the San Dimas Experimental Watershed and Coweeta Hydrologic Laboratory, that the Forest Service committed itself to high-quality work in forest hydrology.

This research eventually began producing a steady stream of research papers that show how the runoff hydrograph in at least small watersheds is affected by specific land use activities and mechanisms. Based on some of this research, we can say the following:

1. Clearcut logging sometimes increases peak discharges and storm runoff volume. The effect is strongest for small storms following a dry period, and strongest in small catchments. As basin size increases, flow frequency decreases, and antecedent soil moisture increases, the effects of logging become less discernible. The generally-accepted conclusion for western coniferous forests is that logging does not increase large peak flows when the ground is saturated (Rothacher, 1971, 1973; Harr et al., 1975, 1979; Wright et al. 1990). Nevertheless, significant increases following clearcutting (up to 39 percent) have been found for rain-generated peak discharges that occur 1 year out of two, in catchments up to 49 ac. in size (Ziemer, 1998).

2. In the rain-snow transition zone, openings in the forest maintain a higher snow water equivalent, and the snowmelt rate is accelerated during rain-on-snow events, relative to the closed forest. This mechanism could significantly increase peak discharges in heavily logged catchments (Harr, 1981; Harr and Coffin, 1992).

3. Road systems increase the area of compaction, intercept subsurface flow, and route the increased surface flow more rapidly to stream channels. These changes may account for changes in timing of runoff peaks and increased peak discharge in small basins (Harr, 1987; Wemple et al., 1996).

4. Deforestation—type conversion can significantly increase peak discharge (Hoover, 1945; cited in Ziemer and Lisle, 1998).

As for the effects of forest vegetation—and its disturbance—on large wet-mantle floods in large river basins, we may never know the answer with any certainty, for at least three reasons. First, large floods by definition occur infrequently, and the time period required for collecting statistically valid data exceeds that of the gaging period record on most rivers. Second, land use changes in large basins are spread over time and space; a clean pre-treatment and post-treatment record is hard to find, and may be confounded with impacts of flood control projects. Third, the downstream routing of floods in large basins obscures local effects; changes in the arrival time of flood peaks may increase or decrease downstream peaks.

All of these problems have plagued efforts to test the widely-believed relationship between deforestation in the Himalayas and flooding in the Ganges-Brahmaputra floodplain. The increased flood damage in the last half-century is attributable to increased settlement on the floodplain. Large-scale deforestation over the same time period in the northwestern Himalayas cannot be identified, and (based on rainfall and river records) the mountains do not seem to have experienced any important hydrologic changes over the period of record available. Furthermore, much of the flooding results from rain on the floodplain itself, and possibly also from construction of levees along the lower river segments (Hofer, 1993; Hamilton, 1987).

Nevertheless, there remain some intriguing papers, such as the one by Lee, Kapple and Dawdy (1975), which showed a change in the rainfall-runoff relationship for Redwood Creek basin after 1964, and the recent controversial paper by Jones and Grant (1996), on effects of logging on peak streamflow in the Western Cascades (see Ziemer, 1998). For now, though, we must conclude that the effects of logging and deforestation on large floods in large river basins is a myth, not as defined above, but in the sense of a real or fictional story (or) recurring theme...that appeals to the consciousness of a people by embodying its cultural ideals or by giving expression to deep, commonly-felt emotions (Morris, 1980). The commonly-felt emotion in this case is perhaps a fear that human activity is causing undesirable large-scale impacts to the landscape.

INDICES OF WATERSHED HEALTH

Hydrologists, especially in the public sector, are faced daily with the problem of evaluating potential hydrologic and geomorphic impacts of proposed projects. Out of a need for quantitative tools, they have developed simple indices that attempt to integrate the potential hydrologic impacts of vegetation removal and soil disturbance on a basin-wide scale. An early example was the equivalent clearcut area method, developed in the Pacific Northwest. This method attempted to estimate peak discharge increases by apportioning the water yield increases associated with vegetation removal. As we have seen, the effects of increased soil moisture on runoff peaks are not distributed evenly throughout the water year.

A second, and more widely used method, the Equivalent Road Area (ERA) approach, was developed in California in the early 1980s. In this method, areas of various types of disturbance are multiplied by the appropriate coefficients to convert all disturbance to the equivalent road area. For example, the area of roads (existing and proposed) is given a weight of 1.0; area of proposed tractor yarding is multiplied by 0.3, cable yarding by 0.1, etc. A weighting factor is sometimes used for slope or geomorphic sensitivity, and historic impacts are included, but discounted at some presumed rate of recovery. The results are then summed in spreadsheets across land type and land use category, and the ERA for the watershed is calculated for comparison with some Threshold of Concern above which cumulative watershed effects are thought to occur.

The ERA method has had the benefit of giving Forest Service hydrologists a tool for negotiating with Timber Management staffs, but it has problems. First, as Harr (1987) showed, there is no threshold for the hydrologic impacts of roads. The more ground disturbance, the greater the impact on runoff peaks (including peaks capable of significant work in channels). Second, even if there were some threshold, there is no good way to determine it a priori. Third, the rate of hydrologic recovery is unknown. Some of the watersheds that might provide some basis for inferring recovery rates—those at Caspar Creek in north coastal California, for example—may have never recovered fully from the impacts of 19th century logging (Napolitano, 1998).

Lacking a firm basis for setting the Thresholds of Concern , what is a poor hydrologist to do?

The answer is simple: set them at a level that will maximize his or her leverage in negotiations on the Interdisciplinary Team that is planning a harvest operation. This is probably not such a bad thing, except that the Timber Management Staff may get wise, and ask to see the numbers.

STREAM CLEARANCE: A GOOD IDEA AT THE TIME

Our last example of myths and misconceptions goes beyond hydrology, touching on fluvial geomythology and fish habitat relationships. In north coastal California, poor logging practices in the 1950s left streams choked with debris jams and aggraded with sediment. The Department of Fish and Game (DFG) decided that removing the debris jams would improve access to upper stream reaches for steelhead and salmon, and allow the excess sediment to be flushed from the channels. Together with the (then) California Division of Forestry and private land owners, and with the active support of Salmon Unlimited, the DFG embarked on a program to remove large woody debris (LWD) from hundreds of miles of streams on the North Coast. In the Noyo River Basin alone, over 0.5 million ft^3 of woody debris were removed from 36 miles of the mainstem and tributaries (Holman and Evans, 1964). Although the importance of woody debris to fish habitat has been well recognized since the mid-1970s (Keller and Swanson, 1979; Swanson et al., 1976; Harmon et al., 1986), the stream clearance programs in north coastal California continued until the mid to late 1980s

The results were disastrous for anadromous fish. The "excess" sediment was soon flushed from the channels, which in some cases began to incise, losing connection with their floodplains and cutting off the backwater areas that provide refuge for juvenile salmonids during high flows. The cleared streams are now mostly devoid of large woody debris, in some reaches resembling trapezoidal flood control channels. To make matters worse, many of the riparian areas in north coastal California are now dominated by red alder, which provides a poor substitute for the large logs and rootwads of redwood and Douglas-fir. It appears in many cases that 1-2 centuries of careful riparian stewardship, along with active replacement of LWD, will be required for the stream systems to return to a "properly functioning" condition. Not much can be said now to justify the program, except that "it seemed like a good idea at the time".

SUMMARY AND CONCLUSIONS

Myths and misconceptions about the relationships between forests, rainfall and streamflow have played a role in American history. The idea that afforestation could increase rainfall was promoted to justify settlement of the arid short-grass prairie and high plains of the west, with unfortunate consequences. Although afforestation in a temperate region cannot increase rainfall, deforestation in the tropics may decrease it.

The supposed relationship between forest cutting and flooding in large river basins figured significantly in the establishment of the Forest Reserve system, which later became the National Forest system. Research in forest hydrology over the last 60 years has shown that although the early ideas about wet mantle floods in large river basins were naive, there are important effects of timber harvest activities on the runoff hydrograph in small catchments.

In efforts to deal with the hydrologic and sediment impacts of timber harvest, forest hydrologists—especially in the public sector—have developed simple indices to indicate the potential for cumulative impacts in watersheds. These indices are not well founded theoretically, but they have provided hydrologists with much-needed tools in their negotiations with timber management staffs.

Among the most destructive myths of watershed management (going beyond forest hydromythology) has been the notion that woody debris jams are bad for anadromous fish. On the basis of this idea, hundreds of miles of streams in north coastal California were cleared of woody debris during the 1960s and 1970s, causing serious damage to habitat for salmon and steelhead. Recovery of the proper functioning of those streams may require 1-2 centuries of active management and restoration efforts.

The history of misconceptions about forest hydrology suggests that 1) we should be very cautious in applying experience gained in one region to problems in another; 2) we should avoid the use of simple indices and formulas for complex problems—there never will be a "watershed health meter"; 3) we should not embark on stream "improvement" programs without first analyzing the fluvial system from a geomorphic and ecological perspective; 4) we should be wary of hydrologic dogma.

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Plenary Session

The Science and Politics of the 1996 Boise Front Fire - What We Have Learned from the 8th Street Fire Rehabilitation Effort[1]

Organizers: *Dave Rittenhouse, Supervisor - Boise National Forest, Boise, Idaho,*
John E. Fend, Area Manager - Bureau of Land Management, Boise, Idaho

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Panelists: *John Thornton, Hydrologist - Boise National Forest,*
Charles R. Mickelson, City Engineer - City of Boise,
Dave Rittenhouse, Supervisor - Boise National Forest,
John E. Fend, Area Manager - Bureau of Land Management,
Fred Pierson, Hydrologist - Northwest Watershed Research Center, USDA Agricultural Research Service, Boise, Idaho
Charles W. Slaughter, Northwest Watershed Research Center, USDA Agricultural Research Service

The 8th Street Fire intensely burned 15,300 acres of highly erodible granitic soils immediately above Boise, the capitol city of Idaho. Below the burnt watershed 12 schools, 3 hospitals, 65 child care facilities, 25 long-term care centers and numerous public buildings, including the Federal building, City Hall and State Capitol. Agency managers, public officials and local citizens all expressed concern about the potential for devastating debris torrents and flash flooding off the burnt watersheds. Several folks remembered the flooding that occurred in 1959 in downtown Boise after a thunderstorm moved over a recently burned watershed just to the south of the 1996 8th Street Fire event.

This presentation discusses the process that was implemented locally to manage the recovery of the burnt watershed while protecting the lives and properties at risk in town. The discussion focuses on how "best science" was utilized by the agency staff specialists preparing the recovery actions and alternatives considered. Additionally, public opinion concerning the recovery methods and the impacts to the aesthetics of the watershed landscape had to be dealt with through many hours of public meetings and workshops. The presentation shares lessons learned in collaboration on a multi-million dollar landscape rehabilitation plan covering 12 different agency jurisdictions. The presentation will also discuss the permanent flood control projects that were constructed by the City of Boise and the extensive cooperation and interaction between local agencies. Follow-up monitoring and research studies continue to make this backyard outdoor laboratory a learning tool for public and federal scientists alike.

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

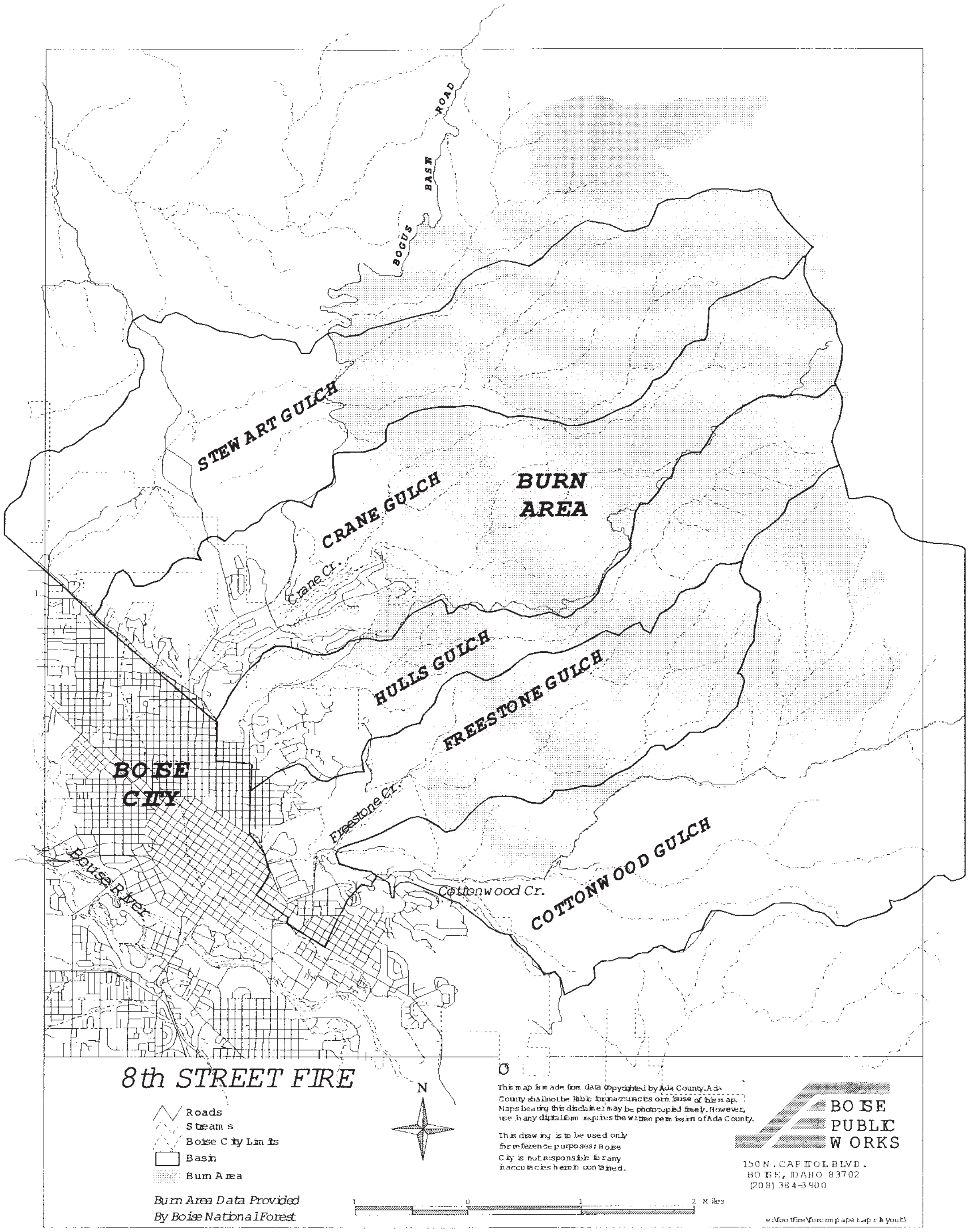

Figure 1. Boise 8th Street Fire area

PARTNERSHIPS, PUBLIC INFORMATION, EMERGENCY PREPAREDNESS AND PROJECTS[1]

Charles R. Mickelson[2]

Abstract. *Immediately following a major fire in the foothills above Boise, Idaho, in August 1996, cooperative actions by local, state and federal government agencies allowed for prompt pre-emergency planning and implementation of pre-emptive actions to cope with possible flooding and sediment deposition in Boise.*

INTRODUCTION

Shortly after the 1996 8th Street Fire, and immediately after the completion of the Burned Area Emergency Rehabilitation (BAER) report, the agencies in charge convened briefing meetings with the Boise City Council and the Ada County Commissioners. These meetings were well attended and as a result of the briefings the Boise City Council and the Ada County Commissioners declared an emergency. The foothills above Boise had burned in the past and thunderstorms had caused serious flooding in 1959; there was serious concern for the potential replay of that scenario following the 1996 fire.

SEDIMENT DETENTION

The Boise City Public Works Department immediately mobilized contractors to begin removing accumulated sediments from pre-existing sediment detention sites in three of the stream courses which lead from the foothills directly into Boise. The sediment basins for Cottonwood Creek and Hulls Gulch were on public property; the sediment basin for Crane Creek was on private property. It had been several years since sediment had been removed from any of these areas, due to extended periods of drought, and substantial amounts of vegetation had grown up in the sediment basins. The sediment removal occurred during September and October of 1996. The City received many complaints at this time from the public who utilized these sediment areas for recreational purposes. This effort provided limited capacity for sediment detention and storage, as compared to the predicted sediment load in the event of a major thunderstorm.

PLANNING

The Natural Resources Conservation Service (NRCS) met with the City Council and County Commissioners and informed them that federal funds were potentially available for downstream flood control projects. Boise Public Works and NRCS staff then developed conceptual sketches and cost estimates for more than 20 projects that could be constructed at, or near, the mouths of the four primary drainages from the foothills through Boise (Cottonwood Creek, Hulls Gulch, Stuart Gulch, Crane Creek). Project concepts included dams, sediment detention structures, trash racks, re-channeling of creeks, and expanding existing detention structures. These project estimates were then utilized by NRCS to secure a $5 million appropriation from Congress which happened to occur on the last day of the 1996 session. The City and County also agreed to a $1.6 million local match for the burn rehabilitation and the flood control projects. The City and County would share the costs equally. The Boise City Public Works Department staff was designated as the project manager for the flood control projects while Ada County was to undertake project management responsibilities for the burn rehabilitation.

The City and County also pursued additional local sponsors (banks, insurance companies, utility companies, the school district, other local and state government agencies and some non-profit groups) to assist in the project funding. Entities targeted were in the high-risk areas that were subject to damages from flooding. St. Luke's Hospital, Boise School District, Farmers Insurance, and the Shakespeare group all contributed funds and United Water Idaho provided free water for the reestablishment of vegetation. Additionally, the Ada County Highway District (ACHD) agreed to pay 15% of the local share. This reduced the City and County's cost share to 42.5% each.

PUBLIC INPUT

In October and November of 1996, Boise City, Ada City County Emergency Management (ACCEM), National Weather Service and BLM conducted a series of meetings to inform the public of the potential risk and possible actions that residents should plan on taking in the event of a major precipitation event. These meetings were attended by more than 1,200 people. Numerous handouts were prepared regarding sandbagging to protect property, evacuation routes, shelter locations, and developing

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

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a buddy system for the elderly and disabled. The City also made available sand and sandbags for the general public. Empty sandbags were distributed from two fire stations. A limit of 20 bags per household was established and fire personnel gave out more than 20,000 bags to the public. Sand was stockpiled at four different locations by ACHD for use by the public. Over a three-day period, the Corps of Engineers also conducted sandbagging workshops for the general public in order to teach them how to fill the bags. These workshops were attended by more than 50 people. The City Public Works Department also filled and strategically located 5,000 bags around the community so that quick mobilization could occur in the event of a flash flood. During the fall of 1996, many businesses placed sandbags near their doorways, window wells and any location that might be vulnerable. During this period there were numerous critics accusing the local officials of over reacting — saying that there was little risk and all we were really after was to capture federal funds to build some public works projects.

In late 1996 and early 1997, ACCEM convened strategic planning meetings of law enforcement, fire, emergency medical, utility companies, Red Cross and other local, state and federal agencies to plan evacuation routes, communications, incident command centers, clean up and disposal sites. These meetings went on for several months and provided an excellent dialogue between the agencies. The Boise City Council and the Ada County Commissioners also decided to install several sirens for evacuation purposes.

PROJECT IMPLEMENTATION

Since an emergency had been declared by the City Council, staff was able to bypass some of the criteria regarding consultant and contractor selection. Early on we determined that the City Public Works Department did not have the manpower available to undertake these project designs in a short time frame. The City began negotiations with Morrison-Knudsen (MK) to provide engineering and construction management services. Staff was also concerned about the length of time that design, permitting and construction would take, so we identified certain critical path activities. These were accelerated where possible. The City Council and County Commissioners were very sensitive to the public perception and directed the staff to pursue public input on these projects regardless of the amount of additional time that was necessary.

The conceptual projects that were identified needed to undergo environmental reviews, public scrutiny and local approval by the Boise Planning and Zoning Commission, the Boise Parks and Recreation Board, the Boise City Council, County Commissioners and ACHD. Additionally, numerous permits were required from the Idaho Department of Water Resources, Idaho Department of Lands and the Corps of Engineers. The initial task order with MK was to assist in the public meetings and to more clearly scope out the potential projects. Several field trips were conducted to review dam sites and locations for the detention structures and the trash racks. During these field trips additional sites were identified as possible locations. With this information in hand and in consultation with NRCS, staff scheduled two scoping meetings where the public was invited. Concepts were reviewed and the public provided input. These meetings met the legal requirements for NRCS environmental review as well as providing very good input as to the projects that would be acceptable to the public. Cottonwood and Hulls Canyon outlets were on public reserves controlled by the City. Concepts that had been proposed were earthen dams with a low flow pipe and an overflow spillway. The public generally opposed dam structures in the reserves. The public process also identified two different sets of issues to deal with - first, two of the drainages were in the City and structures were likely to be constructed on City property and secondly, two of the drainages were in the County and structures were likely to be constructed on State of Idaho or private property. For approvals, design concepts and project development it was decided to split the projects into two general categories - those within the City limits and those in the County. Hulls and Cottonwood were in the City and received the most intense scrutiny by the public. Design objectives were for facilities that would capture the 10-year runoff storm event from a burned watershed.

The Cottonwood drainage was the largest drainage area and had the largest number of institutional buildings with schools, hospitals, senior citizen facilities, two Veteran's homes, the State Capitol and numerous other public buildings. In the Cottonwood drainage there were some existing sediment and flood control basins that had been constructed in the early 1960s. The public suggested that this area, which had already been disturbed in the past, be redesigned and modified to meet the design criteria. The consultants reviewed the information and determined that the 10-year design criteria could not be met at this single location, but by modifying a park facility downstream from the existing basins, storage capacity could be achieved. Construction of flood control facilities in the park would not allow the park to be used for recreational facilities in 1997. This caused a great deal of public outcry and eventually the elected officials decided not to utilize the park for flood control and agreed to a level of protection that provided for the capturing of 65% of the runoff from a 10-year storm event. Excess flows would be channeled through the park and on public right of way to the Boise River.

The Hulls Gulch area had some different challenges. There did not seem to be any good alternatives to a dam or dams in order to meet the design criteria. Boise City had recently acquired property in this area and the committee that had worked on the acquisition did not want dams. There was an old sand quarry site where material had been removed until some time in the 1960s. There was also evidence of ground water in the bottom of the pit based on some old topographic maps. Since the 1970s. the pit had been used as a disposal site for construction debris and excavation material from housing developments. One of the Boise City Council members suggested excavating the pit of the fill material and using it for detention, with the expectation that a wetland could develop in this area. This was eventually accepted and incorporated into the final solution for the Hulls Gulch drainage in conjunction with enlarging an existing pond.

Digging of ponds created a new public and environmental challenge. When dams were being considered for flood control, onsite embankment material would be utilized and only a modest amount of truck traffic would be required to bring construction materials to the dam site. By excavating areas for flood control, the waste material (mostly clean fill) needed to be disposed of properly and in many cases hauled through existing neighborhoods with narrow streets. In addition, there were several schools on the haul routes. Boise National Forest personnel had decided to log much of the burned timber and had suggested using 8th Street as a haul route for some 800 loaded trucks. The public outcry caused the Forest Service to select a different and more expensive route for the logging traffic. In order to excavate the ponds in Hulls Gulch, well over 6,000 loaded trucks, or 12,000 truck trips would be required. When the public and ACHD understood this, new regulations were generated for truck working hours, speed limits, school crossing guards, permitting etc., by ACHD. ACHD also required Public Works to conduct a public education effort with regard to truck traffic safety concerns. These requirements were incorporated into the construction documents.

The next drainages were Crane and Stuart. There were no good detention basin sites on public property due to the steepness of the terrain. There were some suitable sites on private property but the property owners were not willing to grant permission to construct facilities on their property. Dam structures on State of Idaho lands were designed on the East Fork of Crane Creek and on the Main Fork of Crane Creek. In order to minimize the impact of the truck traffic from the Hulls Gulch excavations, the Hulls projects and the East Fork dam were combined into one construction contract. This allowed the construction contractor to haul the excavated material from the Hulls ponds to the dam site to be incorporated into the embankment. This cut the number of truck trips from 12,000 to less than 3,000. The successful contractor for this project also found a disposal site on private property in the foothills and hauled the excess material to that location. This approach substantially diminished the number of truck trips through this North end neighborhood.

The Stuart Gulch drainage offered a unique challenge. Several sites on private property in the lower part of the drainage were evaluated but it was determined that they did not provide storage capacity for the 10-year storm. The final solution that was accepted was to build an embankment on State of Idaho and private property and to reroute a section of Bogus Basin Road (the only route to the local ski area) over this embankment. The public strongly supported this project. The roadway was shortened by more than 1,200 feet, two hairpin curves were removed and the roadway was widened in conjunction with the construction of the flood control facility. The embankment also fully captured the 10-year storm event.

Numerous challenges occurred during construction:

- On the Cottonwood project, the city of Boise was advised that one of our detention pond sites was a military ordnance disposal site in the 1800s. That did not turn out to be true, but an actual military dump and burn site was discovered, which caused delays while the archaeologists evaluated and mapped the site. An old Military Cemetery was previously located under the detention ponds. The remains had been relocated in the early 1900s. Unfortunately, not all had been relocated and during excavation a fully intact coffin and skeleton were unearthed. The remains were removed by the Idaho State archaeologist and eventually interred in the Military Cemetery.

- A flash flood occurred on September 11, 1997. This impacted two of the contractors by flushing sediment and water into their construction sites.

Sediment detention was an extremely important part of these projects. After the projects were completed, sediment basins were nearly filled during the runoff of 1998.

SUMMARY

Cooperative agreements were reached between Boise City, Ada County and ACHD regarding funding of the local share of the flood control projects. Total cost expended locally was nearly $1.9 million. The total project cost, including NRCS share, was $6.8 million.

Extensive public involvement occurred. Two major public hearings were held. The Boise City Mayor and Council, the Ada County Commissioners and the Ada County Highway District Commissioners all attended the same hearings and took formal action to approve the proposed projects at those hearings or shortly thereafter. More than fifty (50) public meetings were held in the period from September 1996 through September 1997. Multiple approvals of agreements, contracts and permits occurred during this period. The public process worked. The projects were improved as a result of public input.

Three construction contracts were completed in the amounts of $2.3 million, $1.4 million and $1.7 million for a total of $5.4 million. Construction started in August 1997 and all contracts were substantially complete by January 1998. Besides flood control, numerous attributes were designed into the projects which benefitted the public including:

- A safer roadway entrance to a school
- A location for an archery range in a detention basin
- A detention basin suitable for a soccer or football field
- Construction of a flood wall to protect the East end neighborhood
- The covering of a portion of an open concrete flume
- The creation of a wetland area
- The realignment of Bogus Basin Road leading to the local ski area

As a result of these constructed projects Boise has significantly more flood control protection after the watershed has fully healed.

Charles R. Mickelson

HYDROLOGIC IMPACTS OF FIRE ON THE BOISE FRONT[1]

Frederick B. Pierson[2]

Abstract. *The Eighth Street fire had a significant impact on the infiltration capacity and soil erodibility across the Boise Front. South-facing slopes had the lowest infiltration and showed the highest rates of erosion following the fire. Two years following the fire, ground cover had not yet sufficiently recovered to fully protect either the north or south slopes from increased runoff and accelerated erosion. Presented results are consistent with observations made following the September, 1997, thunderstorm where the south-facing slopes had the highest concentration of rills and suffered significant soil losses.*

INTRODUCTION: BOISE'S 8TH STREET FIRE

In late August, 1996 a wildfire swept across the foothills above Idaho's capitol city of Boise. Over 15,000 acres of the area commonly known as the Boise Front was completely burned from the city's edge to the crest of the mountains. Following the 8th Street Fire, treatments ranging from shallow ripping to intensive trenching were applied across the Boise Front to reduce the susceptible of the site to severe runoff and erosion. Treatments were chosen based on the assumption that the fire had drastically reduced the infiltration capacity and increased the erodibility of the foothills. Lack of direct information on infiltration conditions on the Boise Front forced decision makers to make assumptions about the degree and length of impact the fire had on infiltration. Management decisions were then made based on those assumptions. By late Fall of 1996, installation of the runoff and erosion control treatments were complete on the entire burned area.

In the summer following the 8th Street Fire the Northwest Watershed Research Center (NWRC), USDA-ARS, began investigating the impacts of the fire on infiltration in soils of the Boise Front. City, county and action agency personnel were eager to gain information to aid them in planning future management responses to the 8th Street Fire and possible future fires in the Boise foothills. The objective of NWRC's investigation was to quantify differences in infiltration capacity, runoff and erosion between burned and unburned areas one and two years following the fire.

STUDY AREA AND METHODS: NWRC'S INVESTIGATION

The study was designed to compare densely vegetated north-facing slopes with sparsely vegetated south-facing slopes under both burned and unburned conditions. All sites were located on steep hillsides with slopes of 40 to 50%. Infiltration capacity, runoff volume and cumulative erosion were measured using simulated rainfall technology. NWRC personnel designed and built a new rainfall simulator for use on such steep slopes. Rainfall was applied at a rate of 2.65 in/hr; runoff samples were collected and analyzed for runoff volume and sediment concentration. Infiltration capacity was calculated as the difference between measured rainfall and measured runoff. Soil samples were collected and analyzed for moisture content, bulk density, organic carbon content and soil texture. Vegetative cover of each plant species and soil surface cover were estimated and vegetative biomass was measured for each plot.

STUDY RESULTS: THE DATA TELL THE STORY

The fire had the greatest impact on intensely burned south-facing slopes , where infiltration capacity was reduced from 2.1 to 1.3 in/hr (Figure 1). North-facing slopes also showed a significant fire effect, but the reduction in infiltration capacity was nearly half (0.4 in/hr) that found for the south-facing slopes.

One important trend found for all burned and unburned sites was that runoff consistently began between two and four minutes after the rainfall started (Figure 2). This very rapid response helps explain why the Boise Front experienced minor flooding in September, 1997 following a thunderstorm of moderate intensity that lasted only nine minutes. The effect of the fire on soil erosion was even greater than its effect on surface runoff. Erosion from the burned south-facing slopes was nearly 40 times that for the unburned south-facing slopes (Figure 3). This was due to the devastating removal of nearly all the vegetative ground cover (Table 1) which protects the soil and most of the soil organic matter which helps to bind soil particles together (Figure 4). Study results two years following the fire showed that soil surface cover on both the north and south slopes had not yet recovered.

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compared to year one. Runoff in year two was similar to year one (Figure 5) and erosion was higher in year two than year for both sites (Figure 6).

CONCLUSIONS: BOISE FRONT FLOODING-1997

The results presented in this report are preliminary and caution should be used when interpreting the conclusions. Results are consistent with observations made following the September, 1997, thunderstorm where the south-facing slopes had the highest concentration of rills and suffered significant soil losses. The north-facing slopes also showed higher erosion levels as a result of the fire, but the highest erosion rates were far less than those for the burned south-facing slopes. Two years following the fire, ground cover has not yet sufficiently recovered to fully protect either the north or south slopes from increased runoff and accelerated erosion.

Frederick B. Pierson

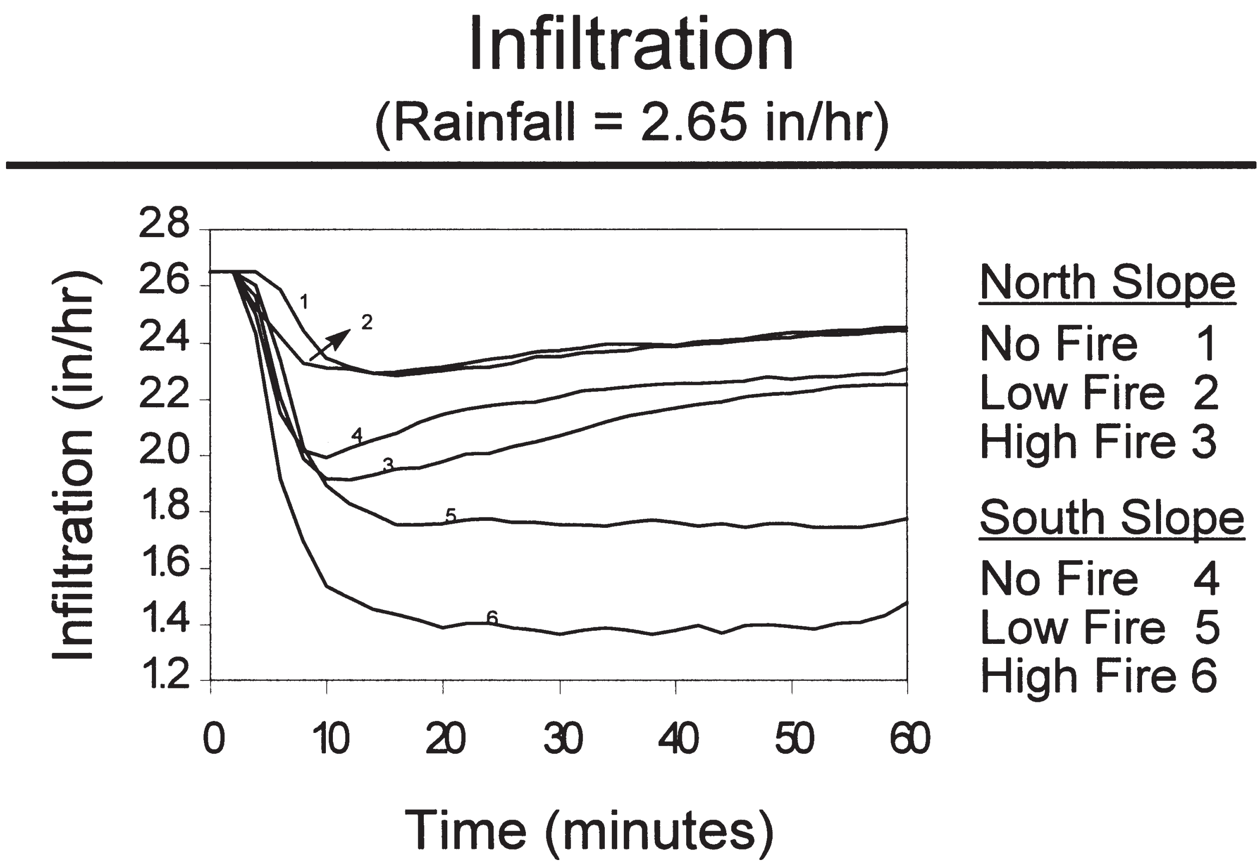

Figure 1. Infiltration rate expressed over time for low and high fire intensity treatments and a no- fire control on both north and south facing slopes, tested using a rainfall intensity of 2.65 in/hr.

Frederick B. Pierson

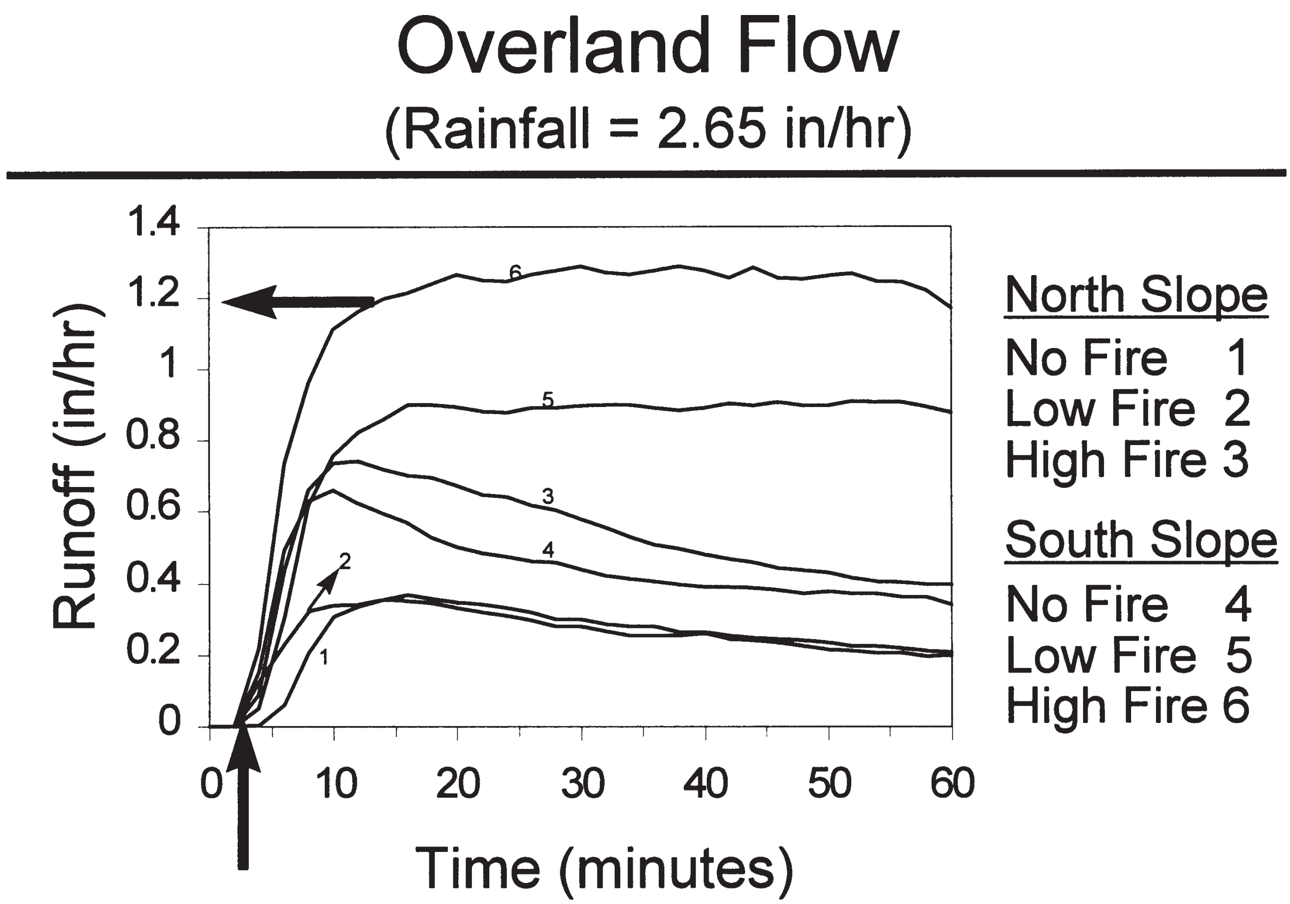

Figure 2. Runoff rate expressed over time for low and high fire intensity treatments and a no-fire control on both north and south facing slopes, tested using a rainfall intensity of 2.65 in/hr.

Frederick B. Pierson

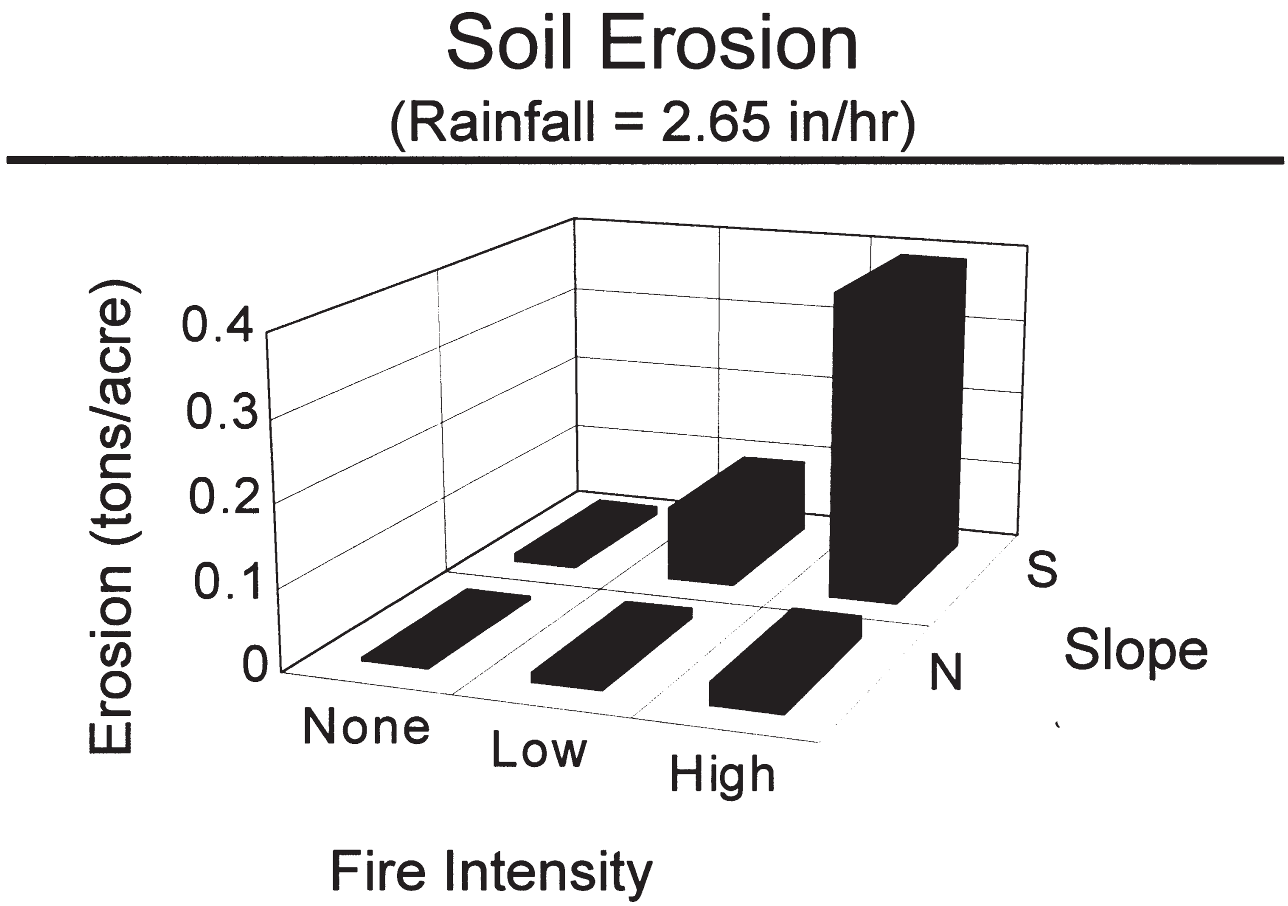

Figure 3. Cumulative erosion for low and high fire intensity treatments and a no-fire control on both north and south facing slopes, tested using a rainfall intensity of 2.65 in/hr for one hour.

Frederick B. Pierson

TABLE 1.

Ground cover of live vegetation, standing dead material, cryptograms, litter, bare soil and rock by aspect, fire intensity and shrub coppice dune (C) or shrub interspace (I) treatments.

Treatment			Ground Cover					
Slope	**Fire Intensity**	**Vegetation**	**Live Vegetation**	**Standing Dead**	**Cryptogram**	**Litter**	**Bare Soil**	**Rock**
North	High Fire	I	3.605	0.002	0	0.9	95.343	0.15
North	High Fire	C	2.205	0.8	0	0.661	96.134	0.2
North	Low Fire	I	1.997	0.15	0	0.811	96.942	0.1
North	Low Fire	C	3.076	0.71	0	1.2	95.014	0
North	No Fire	I	32.387	0.06	5	60.753	1.8	0
North	No Fire	C	13.732	2	0.4	84.928	0.94	0
South	High Fire	I	0.468	0.002	0	0.758	98.772	0
South	High Fire	C	0.736	0.1	0	0.987	98.177	0
South	Low Fire	I	2.111	0.16	0	2.4	95.329	0
South	Low Fire	C	0.693	0.211	0	2.35	96.746	0
South	No Fire	I	2.844	0.002	0	8.6	88.554	0
South	No Fire	C	6.584	0.411	0.15	86.058	6.797	0

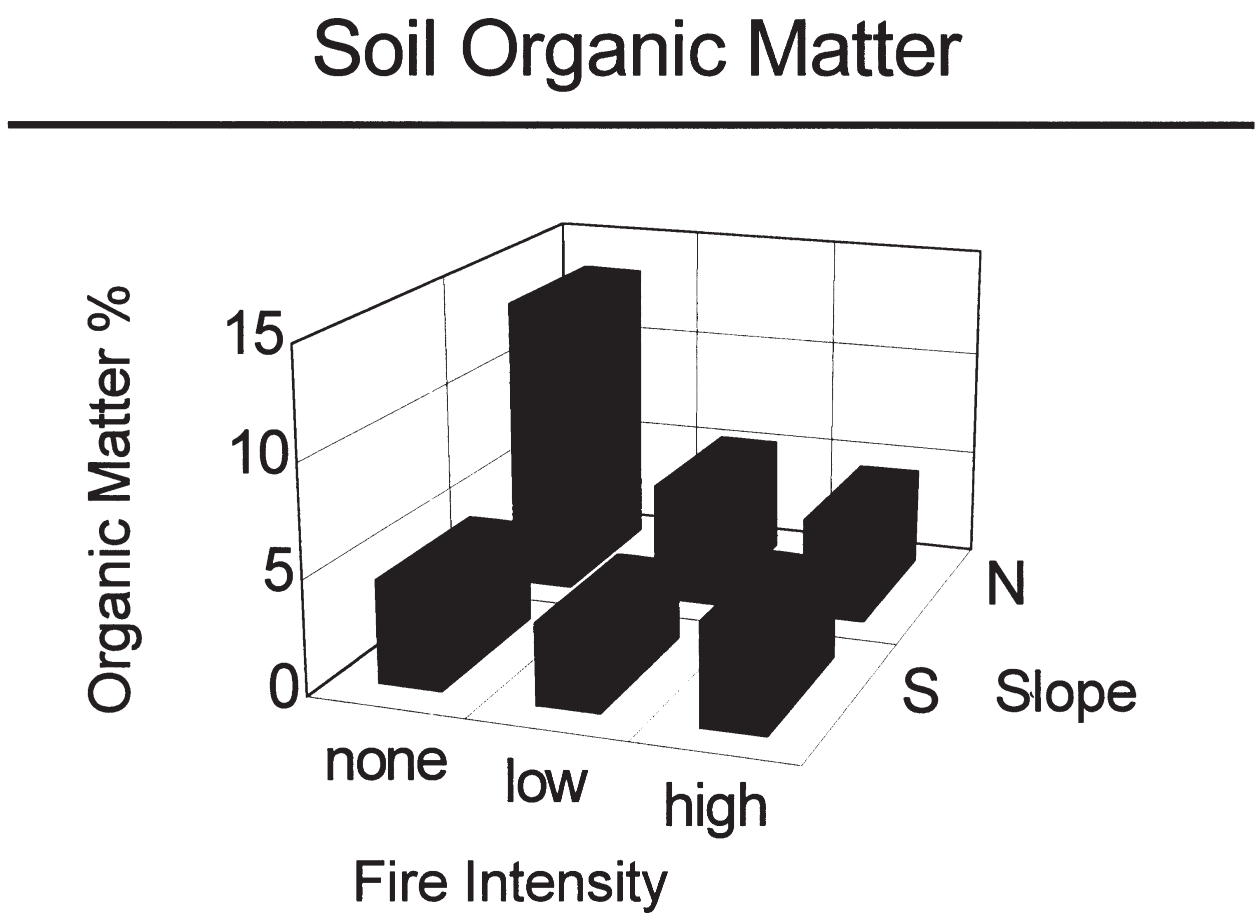

Figure 4: Percent soil organic matter for low and high fire intensity treatments and a no-fire control on both north and south facing slopes.

Frederick B. Pierson

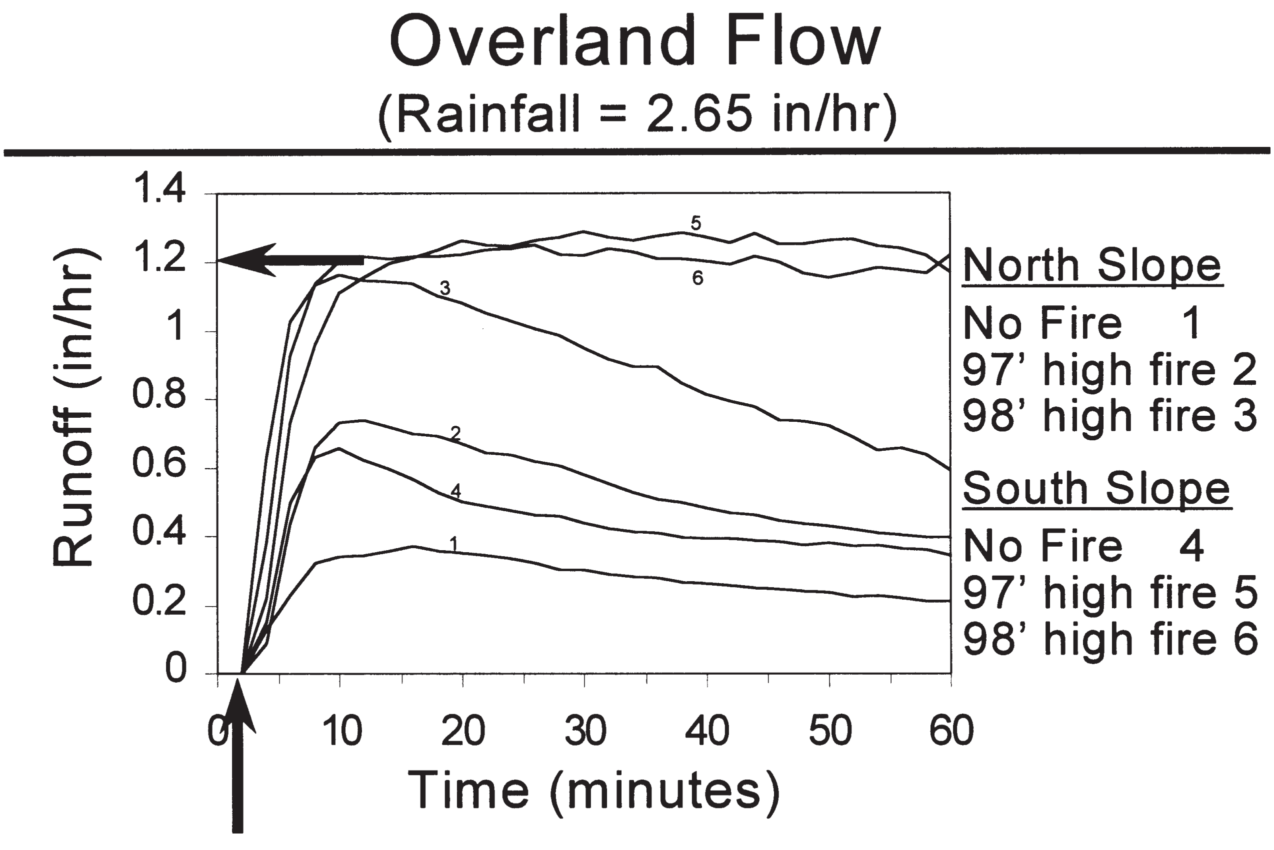

Figure 5. Runoff rate expressed over time for high fire intensity treatments and a no fire control on both north and south facing slopes two years following fire, tested using a rainfall intensity of 2.65 in/hr.

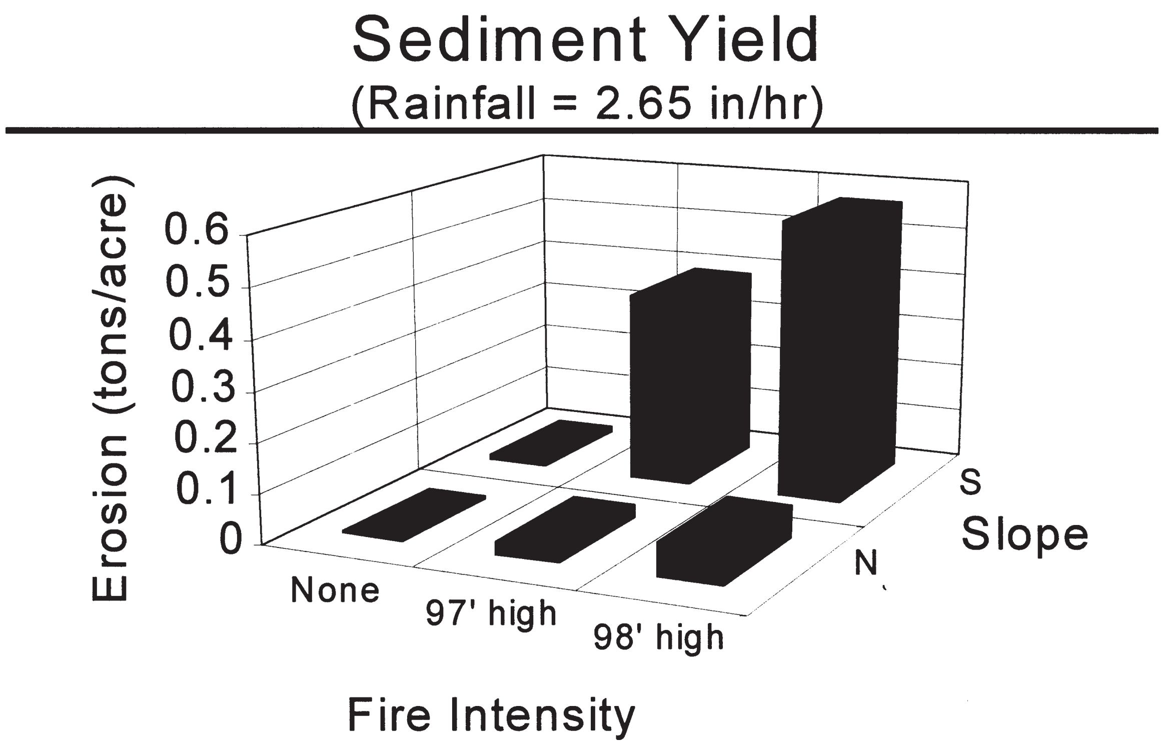

Figure 6. Cumulative erosion for high fire intensity treatments and a no fire control on both north and south facing slopes, using a rainfall intensity of 2.65 in/hr for one hour.

THE SCIENCE & POLITICS OF THE 1996 BOISE FRONT FIRE - WHAT HAVE WE LEARNED FROM THE 8TH STREET FIRE REHABILITATION[1,2]

John F. Fend[3], John Thornton[4], Dave Rittenhouse[5], Fred Pierson[6], Charles R. Mickelson[7], and Charles W. Slaughter[8]

Abstract. *The 8th Street Fire intensely burned 15,300 acres of highly erodible granitic soils immediately above Boise, the capitol city of Idaho in August 1996. Immediately downslope from burned watersheds were 12 schools, three hospitals, 65 child care facilities, 25 long-term care centers and numerous public buildings, including the Federal building, City Hall and Stale Capitol. Agency managers, public officials and local citizens expressed concern about the potential for devastating debris torrents and flash flooding; many remembered the flooding that occurred in 1959 in downtown Boise after a thunderstorm moved over a recently burned watershed just to the south of the 1996 8th Street Fire area.*

This presentation discusses the process that was implemented locally to manage the recovery of the burned watershed while protecting the lives and properties at risk in town. "Best science" was utilized in preparing the recovery alternatives and actions considered. Public opinion concerning the recovery methods and the impacts to the aesthetics of the watershed landscape had to be dealt with through many hours of public meetings and workshops. We share lessons learned concerning collaboration on a multi-million-dollar landscape rehabilitation plan covering 12 different agency jurisdictions. Follow-up monitoring and research continue to make this backyard outdoor laboratory a learning tool for the public and for science.

INTRODUCTION

The August 1996 8th Street Fire burned 15,300 acres and impacted scenic and watershed values, wildlife habitat and recreation. The human-caused fire began in the Military Reserve Park of north Boise on Monday August 26, 1996. Whipped by strong southerly winds on a day of >100-degree air temperature, the fire quickly grew to over 15,000 acres. Firefighters from local, state, and Federal agencies were mobilized. Although hundreds of homes in Boise's foothills were threatened and many neighborhoods were evacuated, only one home was seriously damaged; that home sat at the end of a cul-de-sac, surrounded on three sides by dry grass and brush.. Fire suppression efforts were concentrated on protecting life and property while the fire raced unchecked upslope through brush and grasslands on steep fragile slopes, eventually burning into timber stands in the upper watersheds above Boise.

SETTING

There are five main watersheds draining from the northeast into and through the City of Boise. These include Cottonwood Creek (including Curlew Gulch and Freestone Gulch), Hulls Gulch, Crane Creek, Stewart Gulch, and Dry Creek. From Boise (elevation 2,800 ft.), the watersheds quickly rise to an elevation of over 6,000 ft. along the Boise Ridge. Runoff from these drainages is used primarily for aesthetic and limited irrigation purposes. Several of the watercourses have been engineered under or through heavily populated urban areas, with thousands of homes, numerous schools, hospitals, nursing homes, hazardous waste sites, and commercial properties in the potential flood zones. The foothills area includes a 12,000-acre Area of Critical Environmental Concern and is the primary ground water recharge area for the Boise Front aquifer, which is a primary source of drinking water for the city of Boise.

Soil surveys had classified 90 percent of the foothills as highly erosive lake deposits and decomposed granite. The rehabilitation team estimated that before the fire, the area routinely lost about 2 tons of soil per acre every year. Immediately after the burn, soil loss was estimated at 13 tons per acre per year. The rehabilitation team projected that the lower-elevation slopes would be prone to excessive erosion and flooding for about two years, while the upper elevations would take up to six years to fully stabilize.

[1]Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).
[2]Compiled by C.W. Slaughter, Northwest Watershed Research Center, USDA-ARS
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[7]City of Boise
[8]Northwest Watershed Research Center, USDA Agricultural Research Service

The pre-fire vegetation in 1996 was at high risk to wildfire as a result of many decades of fire suppression. Potential high fire intensities and resulting altered watershed conditions were seen as increasing post-fire risk of accelerated soil erosion, sedimentation, and flooding. The fire burned through land owned or managed by both public and private entities: Boise National Forest 3,160 acres; Bureau of Land Management 4,180 acres; State of Idaho 2,120 acres; Private/City/County 5,840 acres; total fire area 15,300 acres. Four drainages — Curlew and Freestone Gulches in Cottonwood Creek, Hulls Gulch, and Crane Creek — burned from the edge of Boise to their timbered headwaters.

The 8th Street Fire was contained on August 31 and declared controlled on September 2, 1996.

Post-fire Flooding in Boise

There is a history of damaging debris flows and floods following summer thunderstorms on burned slopes in the foothills above Boise. Damaging floods in 1959 (following three foothills fires: Rocky Canyon Fire, 1957, 2,100 acres; Toll Gate Fire, 1958, 650 acres; Lucky Peak Fire, 1959, 9,517 acres) carried large quantities of mud, rocks, and debris into the city of Boise and onto the lowlands east of Boise. Peak discharges in Cottonwood Creek were as high as 9,500 cubic feet per second and 5,380 cubic feet per square mile. The mass of debris (sediment and rocks) transported from these floods was estimated at over 250,000 tons. About 50 blocks of Boise were covered by mud and water with several hundred acres of farmland covered by mud, rocks, and water (a large portion, which is now in urban development). Loss of life was averted by timely efforts of police and nearby residents who warned those in the path of the floods. Flood damage estimates to and around the city of Boise were $500,000 (1959 dollars).

The city of Boise since 1959 has greatly increased in the area, density, and types of development which puts life and property in Boise at a much greater risk than in 1959. The population of Boise in 1960 was approximately 34,000; by 1996 it had increased almost five-fold to 160,000. The Eighth Street fire burned a much larger area and several complete watersheds as compared to the three smaller fires leading up to the flooding in 1959. All of these watersheds drain through and under Boise.

Due to the threat of flash floods and mud slides, the City of Boise declared a local disaster emergency and the Governor of Idaho declared a state of emergency for Ada and Boise counties. The area that was particularly vulnerable contains at least 12 schools, three hospitals, 65 child-care facilities, 25 long-term care centers, and numerous public buildings, including the Federal Building, State Capitol, and City Hall. The area of vulnerability includes over 7000 housing units, has a daytime population of 37,400 and a nighttime population of 16,700 persons, and estimated total private property valuation in excess of $740 million (public property not included).

ACTION TAKEN

Initial Reconnaissance Survey Team

On August 28, less than 2 full days after the fire began, an interdisciplinary/interagency reconnaissance survey team (Forest Service and BLM) was established. This team completed a reconnaissance survey to initially identify issues, agencies, needed disciplines, tentatively locate flood source areas, and determine a plan of action for the BAER (Burned Area Emergency Rehabilitation) team if deemed necessary. This reconnaissance team included the disciplines of hydrology, soils, range, recreation, wildlife, and economics (cost/risk analyst).

The reconnaissance survey concluded that a full BAER survey team was definitely necessary, based on the extreme risk to life and property from potential flood source areas in several watersheds. There was need to notify city and county officials immediately of potential threat of post-fire flooding, accelerated soil erosion and loss of soil productivity. The reconnaissance survey identified several specific issues, including: 404/401 Stream Channel Alteration Permits and Certification would be needed; Heritage Resource assistance would be needed; road access to Bogus Basin Area Ski Area Resort was threatened; numerous towers associated with two large high-voltage interstate power lines may be at risk to flooding/landslides; fire suppression-related surface disturbance, such as bulldozer and hand firelines, if not properly rehabilitated, could substantiality add to risk of soil erosion and flooding; critical big game winter range area for elk and mule deer, and an important grazing allotment, were included in portions of the burned area; three sensitive plant species were identified within the fire area. There was an overall safety concern for data collection and treatment implementation activities.

Loss of an extensive recreational area was a specific concern during and following the BAER survey and implementation activities. This is a major recreation use area for the city of Boise, with an estimated 10,000 visitors per week using the area during the summer for hiking, jogging, mountain biking, trail bikes, horse riding, recreational atv's, and so on.

The 8th Street Fire BAER Survey Team

The interagency BAER survey team had the range of technical skills needed to evaluate site conditions that indicate the effects of the fire on the watershed.

· Hydrologists
· Administrative Officer
· Soil Scientist
· Contracting Specialist
· Recreation
· Public Affairs Specialist
· Geologist/Geomorphologist
· Writer/Editor
· Botanist
· Computer/GIS Services
· Ecologist
· Financial Management
· Cultural Resources
· Infrared Photo Interpreter
· Civil Engineer
· Local Forest Representative
· Range/Plant Materials
· Fire Management Specialist
· Reforestation Specialist
· Visuals/Landscape Architect
· Climatologist
· Wildlife Biologist
· Research
· Law Enforcement

Agencies represented included:

· Boise City Engineering Department
· Ada City-County Emergency Management
· USDA Natural Resources Conservation Service
· USDA Forest Service National Forest Systems
· USDA Forest Service Research
· USDI Bureau of Land Management
· Idaho Department of Lands
· Idaho Department of Water Resources
· Idaho Department of Environmental Quality
· National Weather Service
· Idaho Department of Fish and Game
· United States Geological Survey
· USDA Agricultural Research Service
· US Army Corps of Engineers
· Idaho Power, Inc.
· Bogus Basin Ski Area Resort
· State Bureau of Disaster Services
· U.S. Navy's "Blue Angels"

The team leaders were responsible for assembling and managing the burned-area survey team and for ensuring the survey was completed promptly, to allow completion of the Interagency Fire Rehabilitation Report and subsequent individual agency BAER reports requesting authorization of funding. The Core Teams were:

Hillslopes and Stream Channels (two teams): These teams were comprised of a soil scientist, hydrologist, geologist/geomorphologist, and botanist/plant materials specialist. Their assignments were to evaluate the post-fire conditions of the hillslopes and stream channels while identifying and prescribing treatments for emergency watershed conditions. The field data sheets (HO-4) identifies the minimum data collected by these teams.

Roads and Trails (two teams): These teams were comprised of a hydrologist, civil engineer, and recreation specialist. Their assignments were to evaluate the post-fire conditions of the roads and trails while identifying and prescribing treatments for emergency watershed conditions.

Other teams which covered the entire fire area included: cultural resources; wildlife biologist, T&E plants, range management, landscape architect, and timber/reforestation. These teams worked with the core teams assigned to each watershed and assisted in describing the emergency situation and developed potential treatment measures compatible with their resources.

Additional specific data collection needs or processes initiated during the BAER survey included:

· Review of watersheds drainage through, under, and around the city of Boise and Ada County to assist in determination of risk and exposure to life and property.

· Estimate cost of property and potential lives at risk from flooding.

· Stream Channel Alteration Permit 404/401 process.

· Determination of risk to the Bogus Basin Ski Area and estimating cost associated with loss of this road to the ski area.

· Field review with Idaho Power engineers to determine risk to the two large powerlines and numerous towers crossing the fire area.

· Daily public media field trips and briefings.

· Collection and analysis of climatological (precipitation data)

· Location and development of rehabilitation criteria for fire suppression related efforts such as dozer and hand lines.

Treatment Objectives

Protection of life and property was the primary objective of all treatments. As identified above, there is a significant risk to life and property with a history of actual post-fire flooding to Boise and adjacent areas. The need for immediate implementation of treatments providing maximum reduction in risk to life and property was obvious. However, the decision to use contour trenching with the potential long-term visual impact to Boise required intensive design, testing, analysis, public input, and unanimous support and approval by Boise city and Ada county officials.

The secondary objective was to retain soil onsite to preserve soil productivity, which is foundation for restoring and sustaining the health of these watersheds above Boise. Theses foothills and watersheds provide an important playground and scenic backdrop for Boise and are often referred to as the "Soul of Boise". Rehabilitating these watersheds to avoid long-term disruption of hillslope and stream channel processes is essential.

The remaining objectives focused on the recreational and wildlife resources.

Development of Treatment Alternatives

The selection of treatment measures was based on four considerations: Treatments necessary to protect soil and water resources from unacceptable loss or to prevent unacceptable downstream damage; Treatments that are proven effective and are feasible to implement prior to damage producing storms; Treatments that are environmentally and socially acceptable and compatible with long-term restoration needs; Treatments that have minimal costs while providing essential protection.

Additional considerations included: Need to implement treatments prior to the first damaging storm; Availability of supplies; Access to the areas needing treatment; Work force and equipment availability; Effectiveness of the treatment measures; Possibility of climatic events of more severity than designed for.

Four alternative treatment scenarios were identified:

1. No Action - allow for natural processes to occur while accounting for potential flood threats.

2. Treatments based on similar post-fire watershed conditions but assuming there was no threat to life and property downstream.

3. Maximum treatment to reduce the threat to life and property (without trenching).

4. Maximum treatment to reduce the threat to life and property (including trenching).

It was strongly emphasized from the beginning and continues to be emphasized that none of the alternatives could completely eliminate the potential impacts and risk to the city of Boise from a severe storm.

The final Rehabilitation Report outlined four alternatives ranging from Alternative I (no action) to Alternative 4 (high level of mitigation). The team determined that Alternative 4, Maximum Treatment, was preferred but was contingent upon the input on social acceptance from the city and county leaders and concerned public.

Alternative 4, Maximum Treatment, was ultimately selected and implemented. Alternative 4 recommended:

- Contour felling and hand trenches in forested area
- Contour trenches just below the tree line
- Straw-bale check dams in small stream basins
- Straw wattles on selected slopes
- Tillage on the more gradual slopes
- Seeding and planting

That decision ultimately withstood close scrutiny from several teams of scientists, including a private-industry team commissioned by the Mayor of Boise and a team formed by the Idaho Bureau of Disaster Services.

Treatment Summary

- Log terraces were constructed on 350 acres of burned forest land at the highest elevations.

- At high elevations below treeline, mini-excavators were utilized to construct about 40 miles of trench on 750 acres of steep (40-65 % slope) burned land. Trenches are 2 _ to 3 feet wide and 2 to 3 feet deep, spaced about 75 to 120 feet apart vertically, and partitioned by check dikes at 50-foot intervals to reduce the potential for failure of an entire trench if a local breach were to occur.

- About 1600 acres of moderately steep (30-50 % slope) burned land was treated with straw wattles installed on the contour in a checkerboard fashion, to assist in interrupting overland runoff. Wattles are made of rice straw and photodegradable mesh; individual wattles are 8 inches diameter by 25 feet long, weighing 35 pounds.

- Straw bales were used to build 2,230 check dams across strategid stream channels. Straw bales were wrapped in chicken wire or photodegradable mesh and positioned across the channel in a shallow trench; erosion cloth was draped in front of and across the bales, to allow water to flow through but hold soil in place.

- Mechanical tillage was accomplished on about 700 acres, to increase direct infiltration of rainfall into the soil mantle.

- During the fall of 1996, drill seeding, hand seeding and aerial seeding was accomplished on several thousand acres, using a mixture of grasses and forbs. Some bitterbrush seed was added through dribblers and hand planting by volunteers. In the 1996-1997 winter, part of the burn was aerially seeded with a mixture of basin big sagebrush, mountain big sagebrush, alfalfa, and western yarrow. In spring of 1997 23,000 bitterbrush seedlings and 6,700 silver sagebrush seedlings were planted. It is planned that an additional 180,000 bitterbrush seedlings will be planted on the burn during the next several years.

INTERAGENCY COOPERATION

A Multi-Agency Coordination (MAC) Group was established for the 8th Street Fire which included the BLM District Manager, Boise National Forest Supervisor; Area Supervisor for Idaho Department of Lands; and NRCS Assistant State Conservationist. The purpose of the MAC Group was to iron out any differences between agencies, give unified direction, and review outcomes to make sure goals were met. Adaptive management continued throughout the effort and was the only way to be successful.

There were many minor differences to overcome, but none were big enough to prevent treatment of the burned landscape. Because of necessary coordination among agencies, unit-area cost of treatment was higher; 404 permitting could have gone more smoothly; use of GPS in the very beginning could have resulted in lower contract costs; basic agency differences in policy interpretation caused some difficulties; trespass and access agreements with landholders should have been worked out beforehand to the extent possible.

There were many things that went right. Recommended treatments extended from top to bottom of the watershed and crossed over different land ownerships. Partners pulled together to implement a sound plan – a plan that was validated by the subsequent September 11, 1997, storm and related flood event in Crane Creek. The agencies proved that they could overcome policy differences and get projects done within extremely limited time frames

Communication among agencies at all levels has improved because of this cooperative effort.

HYDROLOGIC RESEARCH

While immediate concern about post-fire consequences centered on hydrologic effects, lack of direct information on infiltration conditions on the Boise Front forced decision makers to make assumptions about the degree and duration of impact the fire had on infiltration. Management decisions were then made based on those assumptions. Treatments were chosen based on the assumption that the fire had drastically reduced the infiltration capacity and increased the erodibility of the foothills.

In the summer of 1997 the Northwest Watershed Research Center, USDA-ARS, began investigating fire impacts on infiltration in the Boise Foothills. The objective was to quantify differences in infiltration capacity, runoff and erosion between burned and unburned areas one and two years following the fire. Utilizing a newly-designed rainfall simulator, water was applied at a rate of 2.65 in/hr and runoff samples were collected and analyzed for runoff volume and sediment concentration.

The fire had the greatest impact on intensely burned south-facing slopes, where infiltration capacity was reduced from 2.1 to 1.3 in/hr. North-facing slopes also showed a significant fire effect, but the reduction in infiltration capacity was nearly half (0.4 in/hr) that found for the south-facing slopes. Runoff consistently began between two and four minutes after the rainfall started.. This very rapid response helps explain why the Boise Front experienced minor flooding in September, 1997, following a thunderstorm of moderate intensity that lasted only nine minutes.

CONCLUSIONS

Even though the 8th Street Fire rehabilitation project had the unanimous support of local and state elected officials and broad support from local residents, by late August, 1997, (the first anniversary of the fire) the decision to accomplish aggressive rehabilitation and flood control work was still being questioned by some residents. Their rationale was that very little erosion had occurred in the damaged Foothills despite an unusually wet winter and spring, while many unburned areas had experienced heavy damage from mud slides. However, we have heard little if any criticism since September 11, 1997, when a 9-minute rainstorm dropped nearly half an inch of rain on a small portions of the burned area, sending muddy water and debris down two major watersheds. The relatively small amount of water and mud that flowed into residential areas at the fringes of the foothills left little doubt that the treatments had helped minimize the damage.

Conference Reflections

REFLECTIONS: LESSONS LEARNED, POLICY IMPLICATIONS FROM WATERSHED SENSE, SCIENCE, STRATEGIES

John Freemuth
Andrus Center for Public Policy
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SCIENCE, POLITICS AND WATERSHEDS: THOUGHTS ON THEIR INTEGRATION[1]

John Freemuth[2]

The move towards a watershed-based approach to the management of our public lands must overcome two fundamental problems. One problem could be called the problem of science, the other, the problem of politics. The two problems are related, as perhaps this premise of mine illustrates: science is a necessary but insufficient condition for public decision making.

Let us start with the problem of science. It has certainly become clear that we cannot make effective rangeland policy without solid scientific information—often the laws require it. As a member of the BLM Science Advisory board I can tell you that one of our key tasks is figuring out how to get science to the managers who need it the most, and understanding barriers to the use of science in that bureau.

Science can be seen as a problem for a number of reasons. One, there is some confusion about which science should be followed. Looking at our national forests for a moment, it is equally valid to apply the science of forestry or the science of ecology to pressing management and policy issues. These sciences offer different perspectives and it is often because they are underpinned by different values. Forestry developed in part with a perspective that looked at forests as tree farms, as places to be wisely managed for the good of society—in this case for the production of goods and services thought have economic benefit for large numbers of people. Ecology, on the other hand, tends to look at forests more as "mother earth", as places to be protected from the ravages of industrial society. Thus, any statements regarding the use of the best science to guide decision makers are rendered problematic at best once we understand the values choices which often lay behind the use of science. Elizabeth Bird put it well when she reminded us:

> *Should we believe everything the science of ecology has to tell us about our relations with nature? Or should we examine the social construction of ecology itself…. and find out if we would want the kind of world that ecology would construct for us if it were to win political hegemony in the sciences.*
> *Mother earth trumps tree farms, as it were.*

Closely tied to this observation is the growing use of what I term "advocacy science" Advocacy science can take two closely related forms. The first clearly mixes up values and science, where what is a clear value preference ends up masked as a scientific truth. The second works by adopting a certain value preference as a policy goal (logging is harmful) and then attempts to "find the science" which demands a certain conclusion that turns out to be the pre-chosen goal (science tells us that logging harms biodiversity, therefore we must stop logging).

Consider the following example. In the December 1994 issue of *Conservation Biology* a fascinating editorial was written about the role of conservation biology in range management questions. The opinion piece takes issue with a question asked by Reed Noss: whether conservation biologists should "link arms with activists in efforts to reform grazing practices?" The authors' conclusions are negative. Worried that conservation biologists would damage their credibility by openly advocating political positions, the authors instead suggest asking a different question. That question is "how can livestock grazing be managed to have the fewest impacts on biodiversity and ecosystem integrity?" The authors claim that a special journal symposium on grazing which precipitated their editorial offered no help on this question. Then, in a powerful conclusion to their editorial we read about

> *The inherent flaw of deductive reasoning which asks one simply to accept "that range management must be dramatically reformed." How could we continue to conduct this research and attempt to develop valid results if we worked from that premise? Our work as scientists involves recognizing patterns based on data and only then formulating a general rule. More importantly, how can we hope to advance the Society's mission to preserve biological diversity if our audience of policy makers assumes that we intend to "prove" a presumed conclusion instead of attempting to falsify well-framed null hypotheses?*

Finally, public trust in expertise, at least expertise in a general sense, has declined. In our own area of natural

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[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

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resources, the public wonders out loud when it is told that fire is good for the watershed, after having been told for years by similar people that “only you can prevent forest fires.” They are buffeted by a myriad of talking heads that talk endlessly to each other about this or that policy topic. Is it any wonder folks turn off their TV’s in disgust, convinced that everything causes cancer and that their views are essentially irrelevant to the greatest experts of the day?

The Problem of Politics

Politics present a different set of problems and issues, which must be understood in order to better, manage and protect watersheds. First, the U.S. political system is designed to check and fragment power, hence moving in the direction of watershed protection takes a good deal of time and effort. Those who advocate for watershed protection need to be fully aware of how our current institutional arrangements affect the success of implementing watershed protection as a management paradigm. Note, though, that these arrangements are based on *assumptions* that lead to structuring of political power relationships in a certain way.

There is no better voice here than that of James Madison, who explains one of the key assumptions of the authors of the Constitution this way:

> *Ambition must be made to counteract ambition…. If men were angels no government would be necessary. If angels were to govern men, neither external nor internal controls on government would be necessary. In framing a government of men over men, the great difficult lies in this: you must first enable the government to control the governed and in the next pace, oblige it to control itself. A dependence on the people, is no doubt, the primary control on the government but experience has taught mankind the necessity of auxiliary precautions.*

The precautions, of course are the commonly understood checks and balances, separation of powers, federalism and republicanism. Power is diffused in the U.S. political system. Policy change is often difficult to achieve.

Madison, in Federalist 10, notes that the one of the most important reasons for checking power is the existence of *factions* (today we would call them interest groups). A faction is “a majority or minority of the whole who are united and actuated by some common impulse of passion, or of interest, adverse to the rights of other citizens, or to the permanent and aggregate interests of the community.” Hence the need to check Madison’s “mischiefs of faction” by representative government, larger political units, and so forth.

Putting all of the above in more modern terms, there is thus a designed tendency of the political system to gridlock and for policy shifts to happen rarely. But, we do know that we have seen examples where our political system overcame the tendency for political gridlock. One example of particular interest to proponents of watershed management is the development of certain policies during the Progressive Era at the turn of the last century.

Practitioners interested in the implementation of an watershed-based management regime would do well to revisit the early days of the Progressive Movement for clues as to how to develop and implement a management regime accepted by an entire society. We remember this era as the time of Gifford Pinchot, Teddy Roosevelt and the birth of the Conservation Movement. The Progressive Era, of course, institutionalized science-based, expert-centered management as a general approach to the growing complexity of society at the time. For example, the federal bureau that best represented the Progressive Era in land management, was the United States Forest Service. Samuel Hays, in his seminal work Conservation and the Gospel of Efficiency noted that:

> *Conservationists were led by people who promoted the “rational” use of resources, with a focus on efficiency, planning for future use, and the application of expertise to broad national problems. But they also promoted a system of decision-making consistent with that spirit, a process by which the expert would decide in terms of the most efficient dovetailing of all competing resource users according to criteria which were considered to be objective, rational, and above the give-and-take of political conflict.*

In the case of the Forest Service, for example, the expertise brought to bear on forest management questions came from the science of forestry.

What is most important about that earlier movement, however, may well be how its themes captured the public imagination. Advocates, as well as students of watershed management, should pay close attention to that earlier time. Gifford Pinchot discovered that “in the long run, Forestry cannot succeed unless the people who live in and near the forest are for it and not against it.” Pinchot helped lead the effort for professional management of the national forests. But, the key to Pinchot’s success lay not solely in his advocacy of professionalism and expertise, but in the service of both to a democratic vision.

In the words of Bob Pepperman Taylor, “For Pinchot the conservation of natural resources is of fundamental democratic value because it allows for the possibility of equality of opportunity (access to public resources) for all citizens.” Taylor adds, “If we remove the vision of Progressive democracy from Pinchot's work, we are left merely with the scientific management and control of nature for no other purpose than brute human survival."

It is also true that later foresters, as noted by David Clary, "became progressively more narrow in outlook as a result of the kind of specialized education they (Pinchot) encouraged." The vision may have become less successful over time because it lost its ability to speak in nonspecialized terms. The point to remember, though, is that early public land management was successful because of its link to a democratic vision accepted by the majority of society at the time, representing an underlying consensus about how a large amount, but not all, of our federal estate should be managed.

The above, however, can be viewed, perhaps, as a roadmap for the eventual integration of today's science and politics. Today there are a number of newer complications that need consideration as well. The first of those is the increasing use of political appointees at lower levels in the public bureaucracies, to move bureau policy in directions sought after by presidents and other senior officials. The term for this phenomenon is the *administrative presidency.* Presidents since Richard Nixon have practiced the strategy. Bureaus, under this strategy, can be subject to policy shifts from administration to administration, which vary greatly and can cause undue stress on professionals within bureaus.

A second complication concerns the push towards collaborative decision making. What remains unresolved is the role of national versus local groups in terms of representation at the collaborative table. The problem is whether national interests have taken the place of local values—say in the case of local and national environmental groups. Environmental values may be represented through local groups, but clearly the national groups have their own *interests* which often lead them to oppose local decision making even when environmental *values* are well represented.

Third, internal bureau organization presents interesting political issues too. Many federal bureaus have dominant professions within them that make up the desired path towards line management positions within the bureau. Any move towards watershed management must take into account the sort of management skills needed for the collaborative, cross-jurisdictional approach demanded. The issue should not be whether degrees in ecology (as, say, forestry before) should dominate the line positions, but what skills make for a good watershed *manager*.

Fourth, we must pay close attention to the definition of the problem we are trying to solve. There is no correct way to define a problem, and defining a problem is a political act. Using ecosystem management as an example, some would say that it is a way to solve the problem of fragmented land management. Others might retort that ecosystem management is itself a problem for those who think it would curtail resource extraction activities.

What is the prescription then? I would suggest that those involved in research, management and protection of watersheds lay out their vision of why our watersheds are worth our protection. But expect to have an active and involved conversation with those who would like to know more, or are in opposition with suggested protection policies that might develop. Science can inform this conversation, but it alone cannot arrive at enforceable goals and purposes for those watersheds. As Wallace Stegner once reminded us: a place is nothing in itself. It has no meaning, it can hardly be said to exist, excerpt in terms of human perception, use and response.

John Freemuth

Concurrent Workshops

Riparian Restoration in Urbanizing Western Watershed Workshop[1]

Workshops Coordinator: *Polly Hayes, USDA Forest Service, 630 Sansome Street, San Francisco, California 94111*

Organizers: *Karen Gaffney, Restoration Projects Coordinator, Circuit Rider Productions, Windsor, California*
Joan Florsheim, Center for Integrated Watershed Science and Management, University of California, Davis 95616
Polly Hays, Watershed Planner, USDA Forest Service, 630 Sansome Street, San Francisco, California 94111

This workshop will address the nuts and bolts of riparian corridor restoration, with an emphasis on preserving, restoring and enhancing native habitats in agricultural areas and in urbanizing watersheds. Detailed project design and implementation issues will be addressed within the context of watershed and riparian corridor assessment and planning. Specific concerns to insure successful native plant revegetation and habitat restoration will be addressed.

Project design and implementation for riparian revegetation projects will be presented in detail, with examples and techniques based on practical experience. Design considerations will include larger scale assessment of historic and existing conditions in watersheds and riparian corridors, and land use constraints. Site specific design topics will include plant procurement, planting layout and densities, and scheduling. Implementation issues will include discussions of planting and transplanting, successful plant protection, identification and control of exotics, and an overview of maintenance needs and techniques.

Application of concepts presented in the workshop will be illustrated with case studies from the Navarro and Russian River watersheds in northern California. The riparian ecology in the Navarro River watershed (785 km2) in Mendocino County has been affected by a century of land use activities including removal of riparian vegetation, grazing, vineyard development and other agricultural activities, logging, and water diversions. Many of these historic land use activities contributed excess sediment to the system leading to channel widening, bank erosion, and loss of riparian vegetation and aquatic habitat. Restoration opportunities for the Navarro River watershed that will be discussed in the workshop include: establishment of a meander corridor; conservation easements; exclusionary fencing; logging road repair; and native plant revegetation.

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

GIS Applications Workshop

Organizer: *James McNamara, Geosciences Department, Boise State University, Boise, Idaho 8371212*

THE SINMAP APPROACH TO TERRAIN STABILITY MAPPING

R.T. Pack, D.G. Tarboton, and C. N. Goodwin[1]

A promising approach to modeling the spatial distribution of shallow translational debris slides combines a mechanistic infinite slope stability model with a steady-state hydrology model. The spatial distribution of a "stability index" is governed primarily by specific catchment area (the up slope area per unit contour length) and slope. The model can be interactively calibrated to the unique characteristics of the topography, rainfall, and soils of a particular study area using simple parameters, graphs and maps. Once a landslide and terrain inventory is completed using aerial photographs, this approach is shown to have the capability of producing a stability classification map of a huge area in a very short time. Analyses of several watersheds in British Columbia are presented as examples.

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USING SINMAP TO MODEL LANDSLIDES IN WEST CENTRAL IDAHO - A CASE STUDY

Mike Dixon, Louis W. Wasniewski and John Thornton, Boise National Forest[2]

The Southwest Idaho eco-group of the U. S. Forest Service, Region 4 has been testing the SINMAP model for use in determining landslide prone areas as required by recent changes in management direction. SINMAP is an ArcView extension that implements the computation and mapping of a slope stability index based upon geographic information, primarily digital elevation data. SINMAP has its theoretical basis in the infinite plane slope stability model with wetness obtained from a topographically based steady state model of hydrology. Landslide data collected in West Central Idaho from the New Year 1997 storm event is being used to calibrate the input parameters of the SINMAP model. Input parameters were calibrated on an area of basalt land types with inventoried landslides. These calibrated parameters were used on a different area on basalt land types with inventoried landslides from the New Year 1997 storm. The calibration parameters were transferable to other areas with similar basalt landforms. Different input parameter values were needed to calibrate an area with schist and gneiss parent material. The SINMAP model performed well in all areas tested, showing increases in inventoried landslide densities with the corresponding stability index. Landslides on granitic land types are currently being inventoried for development of SINMAP calibration parameters. Key to successfully using the SINMAP model for identifying landslide prone areas are: accurate digital elevation data, accurate location of landslide initiation points, and a good sample size of landslide locations. The model has application for broad scale, watershed scale, and project level analysis.

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WHERE IS ALL THAT THE DIRT COMING FROM AND WHAT CAN WE DO ABOUT IT? USE OF SEDMOD TO ESTIMATE DELIVERY OF SEDIMENT TO STREAMS

Domoni Glass[3]

The construction and use of roads in a forested basin can be a significant source of sediment. Road construction removes vegetation from the road cut slope, fill slope, ditch and tread, leaving these areas susceptible to erosion. Over time, the cut slope and fill slope revegetate and erosion from these areas is reduced, however, the road tread and ditch continue to be sediment sources as long as the road is in use. A number of spreadsheet models have been developed that estimate the amount of sediment produced from these road areas. While many of them are good at giving an estimate of the amount of sediment, they simply do not predict where the sediment-input areas are located. Fieldwork must be conducted to determine the location of sediment inputs to a watercourse. The Road Sediment Model discussed here not only determines where these sediment inputs are likely, but also the amount of sediment generated from the associated road length. Currently, the Road Sediment Model can operate without specific attributes for the roads, such as surface type, to give a relative amount of sediment (high, medium, low) and thus can narrow down areas that need site visits. The more road attributes that are known, the more accurate the model; in six watersheds of about 500 square miles total, the model overestimated from 10% to 30% the field checked amount of sediment. This model can be very useful for conducting the soil erosion portion of watershed analysis or for helping to set up a road maintenance plan. With the current emphasis on addressing the legacy road issues in Idaho, Washington and Oregon, this tool could prove to be valuable.

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DEVELOPMENT OF A GEOMORPHIC RISK ASSESSMENT AND USING GIS APPLICATIONS IN THE MIDDLE FORK PAYETTE RIVER SUBBASIN, IDAHO

Jim Fitzgerald[4] ,Terry Hardy[5], and Ted Geier[6]

A geomorphic risk assessment method was developed and is used as a screening tool to delineate watersheds with substantial sediment sources that have high sediment transport potential. This methodology helps assess chronic and acute sources of sediment in watersheds where limited hydrologic data have been collected. For each subwatershed in an analysis area, Potential Sediment Transport and Source Coefficients are calculated using watershed geomorphic characteristics and land use coverages. Watersheds are ranked relative to one another on the basis of their natural and anthropogenic sediment production potential, and their hydrologic potential to store, transport and deliver sediment. Historic and present land use information is used to target watersheds that contain substantial sediment sources for further spatial and temporal source and quantitative sediment budget analysis. Method development and validation was achieved using field data and GIS software and applications. Hydrologic data, resource coverages, and digital information are used to rapidly characterize and analyze the geomorphic and land use characteristics of watersheds. Application to the Middle Fork Payette River Subbasin indicates the proposed methodology is an appropriate tool to screen sediment sources and can be applied over a wide range of watershed scales with supporting GIS information.

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SALMON HABITAT ASSESSMENT IN 6TH CODE WATERSHEDS

Keith M. Reynolds[7]

The Ecosystem Management Decision Support (EMDS) system integrates the logical formalism of knowledge-based reasoning into GIS to provide decision support for ecological landscape assessment and evaluation. The knowledge-based reasoning schema uses an advanced object and fuzzy logic-based propositional network architecture for knowledge representation. The approach affords several advantages over more traditional forms of knowledge representations such as simulation models and rule-based expert systems. The system facilitates evaluation of complex, abstract topics such as forest type suitability that depend on numerous, diverse subordinate conditions because EMDS is primarily logic based. The object-based architecture of EMDS knowledge bases allows incremental, evolutionary development of complex knowledge representations. Modern ecological and natural resource sciences have developed numerous mathematical models to characterize specific relations among ecosystem states and processes, but it is far more typical that knowledge of ecosystems is more qualitative in nature. Approximate reasoning, as implemented in fuzzy logic, significantly extends the capability to reason with the types of imprecise information typically found in natural resource science. Finally, the propositional network architecture of EMDS knowledge bases allows both the ability to evaluate the influence of missing information and the ability to reason with incomplete information. Features of the system will be illustrated with an example of watershed analyses for salmon habitat evaluation in the Oregon Coast Range Province.

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USE OF A GEOGRAPHIC INFORMATION SYSTEM IN Ground water QUALITY STUDIES

Michael G. Rupert[8]

A geographic information system (GIS), which is an organized collection of computer hardware, software, and geographic data, is designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. A GIS can be a valuable tool in all phases of ground water quality studies, and can be used for analysis of historical data, to enhance data evaluation, and to highlight problem areas for future study. An important element of many ground water quality studies is random selection of sampling sites, which helps avoid biasing of data sets and provides the basis for an impartial evaluation of ground water quality. A GIS can be used to randomly select sampling sites and, after those sites have been sampled, the analytical data can be entered into the GIS. Concentrations of analytes can be displayed on the computer screen in color-coded symbols to highlight areas of concern. Also, ground water quality data can be downloaded as ASCII files to a statistical software package for analysis, and coverages of ground water quality data can be "related" with GIS coverages of associated data such as well depth or water levels. Further, more complex analysis of data can be performed using a GIS; for example, ground water quality data can be "overlaid" with other data such as land use or soils and these data can be analyzed by advanced methods such as nonparametric statistics or logistic regression. On the basis of those statistical relations, maps that depict the probability of ground water contamination by particular analytes in specific areas can be developed.

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DEVELOPMENT OF A GEOMORPHIC RISK ASSESSMENT AND USE OF GIS APPLICATIONS IN THE MIDDLE FORK PAYETTE RIVER SUBBASIN, IDAHO[1]

Jim Fitzgerald[2], Terry Hardy[3], and Ted Geier[4]

Abstract. *A geomorphic risk assessment method developed by Geier and Loggy (1995) was refined and is used as a mid-scale screening tool to assess watersheds having a risk of sediment production based on their potential sediment sources and sediment transport. This methodology helps assess chronic and acute sources of sediment in watersheds where limited hydrologic data have been collected. Watersheds are ranked relative to one another on the basis of their natural and anthropogenic sediment production potential, and their potential to store, transport and deliver sediment. Historic and present land use information is used to target watersheds that contain substantial sediment sources for further spatial and temporal source and quantitative sediment budget analysis. Method development and verification were achieved using field data and GIS applications. This method is used to rapidly characterize and analyze the geomorphic and land use characteristics of watersheds. Application of this method to the Middle Fork Payette River Subbasin demonstrates the use of the geomorphic risk assessment, and how GIS applications can rapidly summarize large spatial databases.*

INTRODUCTION

The purpose of this paper is to provide a brief summary of a geomorphic risk assessment (GRA) methodology, demonstrate how Geographic Information System (GIS) tools are applied, illustrate some of the benefits and limitations of GIS, and present an example GRA application. The GRA method was originally developed on the Tongass National Forest in Alaska (Geier and Loggy, 1995). The assessment is used as a mid-scale screening tool and is intended to help develop a conceptual model and risk-based analysis of sediment erosion, delivery and transport. For an expanded description of the methodology refer to Fitzgerald et al. (1998).

[1]*Published in Proceedings of the Seventh Biennial Watershed Management Conference, Charles W. Slaughter, editor. Water Resources Center Report No. 98, University of California, Davis (1999).*

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METHODOLOGY

The GRA is organized so watersheds within a given analysis area are comparable and ranked relative to their natural, existing and potential sediment production, delivery and yield. The analysis steps, illustrated in Figure 1, used to calculate the geomorphic risk coefficients are: 1) watershed stratification; 2) calculation of the Potential Sediment Transport Coefficient; 3) calculation of the Cumulative Source Component; and 4) calculation of the Sediment Transfer Hazard.

Watershed Stratification

The first step in the GRA is to delineate subwatersheds in the analysis area into *pure* and *composite* watersheds. These are the basic units of analysis and are referred to as *geomorphic units* (Geier and Loggy, 1995). Pure watersheds are catchments with no inlet and one outlet confined by surficial hydrologic boundaries. Composite watersheds are catchments with an inlet and outlet, and typically have a high order stream flowing through the middle with a series of low order facing tributaries.

Sediment Transport

The second step in the GRA is to calculate the *Potential Sediment Transport Coefficient* (P_S) for each geomorphic unit (Figure 1). This coefficient attempts to characterize a stream's ability to transport, store and deliver sediment. Use of this coefficient assumes that sediment transport and yield are a function of stream power (Geier and Loggy, 1995). Simply, steep high-energy streams will transport more sediment than low gradient streams. The relief ratio, drainage density, bankfull discharge, and stream gradient are used as surrogates for potential sediment transport.

Stream power is the product of discharge, stream gradient, acceleration due to gravity and the density of water. The magnitude of stream power is a function of climate, drainage efficiency and basin energy. Marston (1978) used relief ratio (R) and drainage density (D) to characterize the efficiency at which watersheds transported water and sediment. This method uses a similar approach to characterize sediment transport potential (Geier and Loggy, 1995). The Potential Sediment Transport Coefficient is the product of relief ratio, drainage density and bankfull discharge ratio divided by depositional stream density:

$$P_S = (E_{mx}-E_{mn}/L_B * L_S/A_W * Q_{unit}/Q_{AA}) / (L_{RSP}+ (0.5*L_{TSP})/A_W) = \text{dimensionless}$$

where:

E_{mx} = maximum watershed elevation at the initial point of drainage (ft.)
E_{mn} = minimum watershed elevation (ft.)
L_B = basin length (ft.)
L_S = total stream length (mi)
Q_{unit} = estimated bankfull discharge for a given unit (cfs)
Q_{AA}= estimated bankfull discharge for analysis area (cfs)
L_{RSP} = total response reach length (< 1.5% slope) (mi)
L_{TSP} = total transport reach length (1.5 to 3% slope) (mi)
A_W= drainage area (mi^2)

As the length of depositional reaches increases, the potential sediment transport decreases. In a steep watershed with high stream density, the Potential Sediment Transport Coefficient will be high relative to a watershed with moderate relief and many depositional channels.

Using bankfull discharge as a variable in the Potential Sediment Transport Coefficient helps account for long-term climatic trends present in a given basin and is an attempt to limit the effects of annual variability. Bankfull discharge is estimated for the analysis area and each contributing subwatershed. Several methods are available to estimate bankfull discharge at ungaged sites: for example, U.S. Geological Survey regional flood equations (e.g., for Idaho, Kjelstrom and Moffatt, 1981), empirical curves presented by Leopold et al. (1964), and field identification (Rosgen, 1996). Field identification of bankfull stage requires that discharge be either estimated using the slope-area method (Benson and Dalrymple, 1967) or measured. In addition to potential stream power, the ability of a stream to transport sediment is influenced by valley and channel slope and confinement, substrate characteristics, and volume of large woody debris. Generally, low gradient channels with high width to depth ratios will store sediment, whereas, high gradient confined channels will tend to transport sediment (Rosgen, 1996; Montgomery and Buffington, 1993). To account for instream sediment storage this method uses the depositional stream density (D_R) which is similar to drainage density and is the quotient of a given unit's length of response or depositional reaches to drainage area (Figure 1). This variable assumes that a high depositional stream density is proportional to high instream sediment storage.

<u>Sediment Sources</u>

Natural and anthropogenic *Sediment Source Coefficients* are developed to stratify watersheds based on their high natural sediment yield and/or management induced sedimentation. These coefficients can be used individually to rate watersheds or summed and used to adjust the Potential Sediment Transport Coefficient. Additionally, through the exercise of summarizing sediment source information, maps of the locations and ages of sediment sources are produced.

The number and type of source coefficients are site specific and user defined: for example, in watersheds where agriculture is the common land use the erosion factor K from the Universal Soil Loss Equation could be used as a surrogate for natural sediment sources. Any source coefficients should be defensible and fully explained in the analysis. Additionally, background sediment production and yield should always be factored into the source analysis.

Watershed source coefficients are scaled or normalized to the highest value. If the source coefficient is used to adjust the Potential Sediment Transport Coefficient this convention eliminates weighting components. There are four source components developed as part of the example presented below. These include: 1) natural source component; 2) riparian road component; 3) harvest area component; and 4) mass wasting component (Figure 1). For a description of these source coefficients refer to Fitzgerald et al. (1998).

<u>Sediment Transfer Hazard</u>

The final step or calculation in the GRA is simply the product of the Potential Sediment Transport Coefficient and the Cumulative Source Coefficient. The product of these two coefficients is a dimensionless *Sediment Transfer Hazard*. This coefficient is the final GRA variable used to evaluate the risk of sedimentation.

GIS APPLICATIONS

GIS applications were used as part of the assessment process to rapidly summarize and query large data sets, analyze spatial information, and display assessment results. ArcInfo and ArcView are the core software used in the assessment. Five map or resource coverages provided the majority of spatial data. These coverages include: 1) watershed boundaries; 2) waterbodies (streams and lakes); 3) geology and soils; 4) road information; and 5) land use history. Other coverages incorporated into the analysis include: 1) aerial photos; 2) digital elevation models (DEM); 3) digital ortho photos; 4) digital quadrangles/ topography; and 5) other land systems information.

GIS LIMITATIONS

GIS applications are an effective tool which can be used to rapidly summarize and analyze spatial data. The certainty of any analysis, however, is greatly influenced by the resolution and age of the GIS database.

Coverage scale is one of the greatest factors which influences the uncertainty associated with the GRA components. Because watershed and stream mapping is scale dependent, coarse scale maps will typically have less accurate watershed and stream coverages. Coarse scale coverages will influence how watersheds are stratified and may introduce error into the GRA calculations: for example, drainage density will be underestimated if it is calculated using data derived from a 1:100,000 scale stream coverage.

The accuracy and precision of the source components are also limited by the scale of mapping. The reliability of source components is also influenced by the age of the data. For example, the Riparian Road Component is limited by the road and stream coverages used in the analysis. The accuracy of the road network coverage is limited by the scale of mapping and the age of the most recent road inventory. Old or incomplete inventories may introduce large error into the GRA analysis.

EXAMPLE: MIDDLE FORK PAYETTE RIVER

Background

The Middle Fork Payette River is located in the southern Idaho Batholith, drains about 339 square miles and has a stream density 2.4 miles per square mile (Figure 2). The mainstem drains to the southwest contributing to the South Fork Payette River. Elevation ranges from about 3,000 feet near the Middle and South Forks of the Payette River to 7,500 feet near the headwaters. Figure 2 illustrates the subwatersheds used for this analysis, and Table 1 summarizes the characteristics of the pure and composite subwatersheds that drain to the mainstem Middle Fork Payette River. As previously defined, *pure* watersheds have no inlet and one outlet, and *composite* watersheds have an inlet and outlet.

Results and Discussion

Application of the GRA has produced ratings that identify subwatersheds of the Middle Fork Payette River Subbasin which likely produce the greatest sediment loads and need further quantitative sediment budget analysis. Figures 3 and 4 summarize the results of this analysis. The cumulative source coefficient and sediment transfer hazard were calculated to illustrate there use, however, the values produced by these component are limited because each source component is weighted equally.

Pure Watersheds

The pure watersheds that likely have the highest potential to transport sediment to the mainstem Middle Fork Payette River are: 1) Bull; 2) Silver; 3) Bulldog; 4) Lightning; 4) Scriver; and 5) Anderson Creeks (Figure 3).

The following pure watersheds have the largest amount of natural sediment production: 1) Anderson; 2) Lightning; 3) Bulldog; 4) Silver; 5) Wet Foot; 6) West Fork; and 7) Sixmile. However, of these watersheds, only Bulldog, Anderson, Lightning, and Silver have high Potential Sediment Transport Coefficients (Figure 3). The watersheds with the largest amount of existing vegetative management are Anderson, Scriver, West Fork and Sixmile. These watersheds also have the highest Cumulative Source Coefficient. The natural, riparian road and harvest components positively correlate with Cumulative Source Coefficient.

Composite Watersheds

The Rocky Canyon composite watershed has the highest Potential Sediment Transport Coefficient, and Groundhog and Pyle Creeks have moderate sediment delivery potential. Groundhog, Bridge and Rocky Canyon composite watersheds have high natural sediment yields. However, because Groundhog and Rocky Canyon have low riparian road and harvest components they have low Cumulative Source Coefficient (Figure 4). Bridge Creek has the highest Cumulative Source Coefficient but has a low Potential Sediment Transport Coefficient relative to other composite watersheds.

GRA Risk

As a final step, risk ratings are interpreted and subwatersheds are targeted for further analysis. Because the Potential Sediment Transport Coefficient and the Cumulative Source Coefficients are dimensionless, the product of the two (i.e., Sediment Transfer Hazard) should indicate which watersheds are likely to be the most substantial contributors of sediment to the Middle Fork Payette River. Based on the results Anderson, Scriver, Lightning, Silver, and Sixmile have the greatest risk of producing, transporting and delivering sediment to the mainstem. The composite watersheds Pyle, Rocky Canyon and Bridge are also areas of concern, however, the Lake watershed (C2) has a substantially greater Sediment Transfer Hazard.

Further evaluation of these high risk watersheds should include: 1) a more detailed analysis of road properties and condition; 2) quantification of mass wasting inputs and temporal frequency; and 3) quantification of the annual sediment contribution. Figure 5 illustrates the components of the sediment budget.

Summary

In summary, this paper provided a brief summary of a GRA methodology, demonstrated how GIS tools are applied, illustrated some of the benefits and limitations of GIS, and presented an applied example. The GRA is shown to be an effective tool to rapidly screen watersheds on the basis of physical attributes and available sediment sources using information and data commonly available (Geier and Loggy, 1995). This method uses surrogate measures to characterize a watersheds potential to produce, transport and deliver sediment. Its flexible nature allows it to be altered as a function of the question or problems being asked while maintaining the fundamental logic and assumptions. This is not a “black box” method, however, and the output is only as good as the input data (Geier and Loggy, 1995).

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Roads/Watersheds Technical Workshop

Organizer: *Michael J. Furniss, USDA Forest Service, Stream Systems Technology Center, 240 West Prospect, Fort Collins, Colorado 80526*

RECENT ROAD RESEARCH AT THE ROCKY MOUNTAIN RESEARCH STATION

Randy B. Foltz[1]

Aggregate Quality: For three winters a study was conducted that compared a "good" quality aggregate to a "marginal" quality aggregate on the Lowell District of the Willamette National Forest. This study used natural rainfall and had logging truck traffic. Both aggregates were basalt geological parent materials and differed primarily in the Sand Equivalent and the Los Angeles Abrasion tests. Although termed "marginal" by the Willamette NF, road engineers from other forest stated they would be happy to have rock of that quality.

Sediment production from the running surface on the 150 foot long test sections subjected to identical logging truck traffic was measured. The "marginal" quality aggregate produced from 3 to 17 times as much sediment as the "good" quality aggregate. The processes believe to be responsible for the differences were amount of rutting on the running surface, crushability of the aggregate, and water flow path length differences. Following these series of tests, eighteen aggregates from WA, OR, ID, UT, and SD were collected. The aggregates consisted of a mix of "good" and "marginal" aggregates. Each aggregate was widely used in the region from which it was collected. Each aggregate was compacted to 95% of optimum density and subjected to a controlled high-intensity rainstorm during which the sediment runoff was measured. Following this rainstorm, the equivalent of 200 passes of a loaded logging truck and 200 passes of an unloaded logging truck was applied to the aggregate. Another rainstorm followed the traffic simulation. Sediment production from the eighteen aggregates were compared both before and after the traffic. Sediment concentrations before traffic ranged from 0 to 12 g/l. After traffic sediment concentrations ranged from 1 to 24 g/l. The best single indicator of sediment production potential appears to be the percentage passing a number 40 sieve. These two studies show that all aggregates are not the same. Careful attention to aggregate tests should be paid when selecting aggregate to mitigate sediment production.

Geological Parent Material: Several watershed analysis methods use geological parent materials to determine erosion. The Rock Mountain Research Station has collected simulated rainfall runoff data for the past 10 years from a wide variety of geological parent materials. Sediment produced from the different parent materials varies by a factor of 14:1 from Mica Schists to Belt Series soils. This data set of 10 geological parent materials should be incorporated into watershed analysis.

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USEFUL TOOLS FOR EVALUATING ROAD EROSION IN WATERSHEDS

William J. Elliot[2]

The Water Erosion Prediction Project (WEPP) Model has been under development for over ten years. In recent years, templates and user-friendly tools have been developed to allow users to quickly apply the WEPP technology to determine the impacts of road erosion in watershed. Three tools will be demonstrated: The X-DRAIN program, released in September, 1998; the WEPP:Road interface, currently under development by the Rocky Mountain Research Station, scheduled to be released in late 1999, and road templates for the WEPP DOS interface. These three tools will be demonstrated and the strengths and limitations of each of them will be discussed.

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ENVIRONMENTAL RISK ASSESSMENT OF WILDLAND ROADS ACROSS SCALES

Michael J. Furniss[3]

Understanding the risks of wildland road systems to watershed function and aquatic habitats and organisms has received a high level of emphasis lately, especially on public lands in the west. Large-scale assessments of aquatic systems have identified roads as important sources of adverse effects. Yet all roads do not have the same effects, but rather exhibit a wide range of effects, both in degree and mechanism. There is a pressing need for methods that can determine what roads are affecting what values by what mechanisms across large land areas. The Forest Service has recently begun a concerted effort to take a much-needed hard look at a legacy of more than 400,000 miles of roads on National Forest lands, in response to Chief Mike Dombeck's natural resources agenda, which emphasizes watershed health and restoration, sustainable timber production, recreation, and road policy reform.

Site-scale research and technology for the control of adverse watershed effects is relatively well developed. Approaches to intermediate-scale (e.g., watershed, 5th field) and larger-scale assessment of road effects that effectively inform decisions are not well developed, although a variety of examples have recently become available from across the country.

The presentation will discuss the principles of risk assessment and how they relate to the watershed effects of roads in wildland environments, describe and critique a range of approaches that are being used, and demonstrate some of the scale considerations that are needed if large, intermediate and site-scales are to be effectively linked, creating assessment and planning strategies and products that are feasible, useful, and effectively enable public land management agencies to make well-reasoned decisions about future transportation systems on public lands.

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Poster Session

Managing Western Watersheds - Successes and Lessons

Organizer: *James Bergman, USDA Forest Service, Truckee Ranger District, 10342 Highway 89 N. Truckee, California 95734*

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MOVABLE BARRIER FLOODWALL SYSTEM[1]

The MBFS is an automatic dynamic levee system that is operable solely by the buoyant forces of water. In the preferred embodiment, a series of gasketed composite walls weighing approximately 20 lbs. per cu. ft. are fitted inside a double-sided concrete channel trough. These structures are mounted along one or two sides of the riverbank, (in or outside the river) or on top of existing levees in a parallel orientation to the river. The purpose of the invention is to be able to raise the existing flood protection level an additional five to twelve feet in height when needed and then disappear when not needed. Many additional benefits, beyond the aesthetic values, are created by the MBFS. The MBFS is rated to last between 50 to 75 years. The MBFS requires a minimum amount of maintenance. All parts are easily removable for inspection, repair or replacement.

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THE USE OF COMPARATIVE WATERSHED HYDROLOGY FOR ASSESSING IMPACTS TO RIPARIAN FUNCTION AND STREAM CONDITION[2]

The theory behind the assessment of riparian function is predicated on the assumption that a properly functioning condition riparian area can withstand the forces associated with moderate to high flow (4 to 5 percent probability) events. However, severe flow events can negatively impact riparian areas and streams that are in good condition and continually degrade streams that are in a vulnerable condition. Changes in watershed hydrology associated with land use changes can have a dramatic impact to sediment and water supplied by the watershed. These changes can increase the frequency at which damaging flows can occur within a given watershed. The Cottonwood Creek watershed in north central Idaho has undergone a dramatic change in land use and land cover types during the last 100 years. This change has led to increased water and sediment discharge during rain on snow events and may be in part responsible for degraded stream conditions within the watershed. The Natural Resources Conservation Service Technical release 20 (TR20) hydrology model was employed to access the relative change in watershed hydrology from historical conditions to present conditions. The TR20 relies heavily on runoff curve numbers to generate storm event hydrographs. In order to use the model for comparative purposes, soil surveys were used to determine past land cover types for developing historic runoff curve numbers. Current and historic runoff events were plotted on dimensionless hydrographs to assess only the relative change in stream discharge over base flows during storm generated runoff events. Modeled current two-year event flows are 2.3 times higher than modeled historic discharges and modeled 25 year events are 1.7 times higher that predicted historic flows. Using comparative watershed hydrology has enhanced the ability of planners to determine the impact of altered watershed hydrology on riparian and stream systems within the Cottonwood Creek drainage.

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STREAM CHANNEL AND STREAM-EDGE WILLOW RESPONSE TO EARLY SUMMER GRAZING IN A MOUNTAIN MEADOW[3]

When managing riparian systems the maintenance of hydrologic function and aquatic habitat is, or should be, a primary concern. This presentation emphasizes the response of certain stream channel and stream-edge willow community characteristics to several intensities of early summer cattle grazing in a cold mountain meadow location. The grazing intensities were: light (~15 cm of streamside forage stubble; ~21% streamside and ~25% dry meadow biomass utilization), medium (~10 cm of streamside forage stubble; ~35% streamside and ~49% dry meadow biomass utilization), and no grazing. Channel bottom characteristics (embeddedness and substrate composition), that are influenced by upstream activities, generally showed no change or slight deterioration under medium grazing while light grazing and no grazing generally showed no change or an improvement. Bank stability increased under all treatments as did willow height, cover, and biomass at the stream edge. Bank alteration, stream width, and stream width/depth ratio decreased under all treatments. Collectively, these results show improvements in most stream channel and willow community characteristics occurred when grazing was at medium intensity or less and limited to the early summer period during this 10-year study. The rate of improvement was however, often inversely proportional to grazing intensity.

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WEPP DERIVATIVES: TEACHING AN OLD DOG NEW TRICKS[4]

The Water Erosion Prediction Project (WEPP) Model has been around since 1989. Numerous improvements have been and continue to be made in the scientific code of the model, and the greatest current focus is on improving the interface. WEPP requires over 400 input variables for a run, and many potential users have not adopted the model because of the difficulty of the current interface. In spite of the difficulty however, WEPP predicts soil erosion for a wide range of conditions, including forests. It estimates not only hillside erosion, but also sediment delivery and the size distribution of eroded sediments. We have developed WEPP templates to describe forest roads, skid trails, a range of burned conditions and regeneration following fire.

To capture the WEPP technology for users who do not have time to become familiar with the current interface, we are developing a number of WEPP Derivatives. The first derivative, X-DRAIN, was released in September, 1998. It allows the user to determine the impacts of cross-drain spacing, topography, soil, and road location on sediment delivery to the stream. It should allow users to rapidly predict the impact of a road network anywhere in the U.S. X-DRAIN presents the results from 50,000 WEPP runs for a set of specific climates, soils, and topographies. For individuals who wish to consider conditions not applicable to X-DRAIN, we are currently developing WEPP:Road. The WEPP:Road interface allows users to enter any topographic condition, and generate any climate for their specific conditions. They can also access greater information in the WEPP output file than available with X-DRAIN. Erosion risk is dependent on the level and distribution of disturbance, and the erosivity of the climate. The WEPP model can provide the data to estimate risks of erosion associated with forest disturbances for any climate. We will be developing an interface to provide risk analysis for users directly from the interface.

[4]*William J. Elliot, USDA Forest Service, Rocky Mountain Research Station, 1221 S. Main, Moscow, Idaho 83843*

REVISITING FEMAT FOR EFFECTIVE RIPARIAN MANAGEMENT[5]

Due to recent listing of anadromous fish stocks under the federal Endangered Species Act, numerous private landowners and government agencies are working to improve freshwater habitat conditions for spawning and rearing salmonids. Riparian buffer standards are a central element of these habitat improvement efforts. On commercial timberlands one of the challenging tasks is to provide buffers that will deliver adequate large woody debris (LWD) into streams. Effective pieces of LWD generally consist of fallen trees in large diameters, and large trees are a valuable economic resource. The report of the Forest Ecosystem Management Assessment Team (FEMAT, 1993) contains generalized curves showing the percent of riparian function that can be achieved as a function of riparian buffer width. These curves are widely cited and used by government agencies and scientists in relation to planning, and negotiating, riparian buffers on private timberlands. The FEMAT cure for LWD shows that the cumulative effectiveness of the riparian buffer increases in a linear manner with increasing distance from the stream, until the slope flattens abruptly. If we examine data from published studies a very different pattern is clearly evident. Field data demonstrate a curvilinear relationship, where cumulative effectiveness increases rapidly close to the stream and gradually tapers to a flat slope. The field data suggest that trees growing close to the stream are more likely to deliver LWD than the FEMAT curve would indicate. The contrast between field data and the FEMAT curve for LWD has important implications for any effort to develop effective riparian buffers in an economically efficient manner. The scientific, regulatory, and management community should revisit field data and modify FEMAT curves accordingly.

[5]*James C. Gaither Jr., California Resources Agency, 1416 Ninth Street, Suite 1311, Sacramento, California 95814*

THE BEHAVIOR OF FINE DEBRIS-TORRENT DERIVED SEDIMENTS IN THE NORTH FORK BOISE RIVER, 1995-1997[6]

In August 1995, large volumes of fine sediment were deposited into the North Fork Boise River and two of its main tributaries by debris torrents. An accompanying flood distributed the fine sediment throughout the channel. The event also provided the opportunity to examine the movement of fine sediment over a coarse bed in a natural channel. This project uses large-scale aerial photographs to examine the movement of the fine sediment through the channel over the following two years. The distribution of fine sediment volume is estimated from photo measurements that are calibrated using field data. Results indicate that the majority of fine sediment was moved out of the channel by the first spring runoff event. During the second year, a winter rain-on-snow event and summer thunderstorm each produced smaller debris torrents with localized effects.

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[6]*Julie Gott, Lake Tahoe Basin Management Unit, USDA Forest Service, South Lake Tahoe, California 96150*

MONITORING THE REHABILITATION TREATMENTS FOR THE EIGHTH STREET FIRE: A COORDINATED EFFORT[7]

In August of 1996, the Eighth Street Fire burned over 15,000 acres in the foothills adjacent to the City of Boise. In the wake of this fire, federal, state, county, and city agencies all participated in a massive rehabilitation effort that included soil stabilization and reestablishment of vegetation. Rehabilitation efforts involved lands of mixed ownership. Due to the tremendous expense involved in this rehabilitation effort, and the public exposure, it was necessary that monitoring be done to determine how successful the treatments were, and recommendations in the future for similar situations. An interdisciplinary team developed a monitoring plan which identified three separate work groups. One group dealt with the response of vegetation, one with the effectiveness of soil stabilization treatments, and one with fire and treatment effects to infiltration and runoff. The individuals who participated on the work groups were professionals from Boise National Forest, Natural Resources Conservation Service, Idaho Department of Lands, Idaho Department of Fish and Game, Bureau of Land Management, Agricultural Research Service, and USFS Intermountain Research Station. The poster will briefly describe monitoring objectives and procedures which are continuing into the third year for each work group.

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[7]*Leah Juarros, USDA Forest Service, Boise National Forest, 1249 S. Vinnell Way, Boise, Idaho 83709; Frederick Pierson, Northwest Watershed Research Center, USDA Agricultural Research Service, 800 Park Boulevard, Boise, Idaho 83712; Lynn Wessman, Lower Snake River District, USDI Bureau of Land Management, 3948 Development Avenue, Boise, Idaho 893705*

WINTER PRECIPITATION ESTIMATION USING NEXRAD AT THE NORTHWEST WATERSHED RESEARCH CENTER: PRELIMINARY RESULTS[8]

Rainfall studies at the Northwest Watershed Research Center primarily have used rain and snow data from rain gauges, snow pillows, or other in situ measurements. Recent advances in radar remote sensing retrieval of precipitation, and the deployment of a new weather radar in Boise in 1995, have prompted the application of these measurements to estimating rainfall and snowfall rates and accumulations using NEXRAD (Next Generation Weather Radar, WSR-88D) at the Reynolds Creek Experimental Watershed.

NEXRAD precipitation retrievals require use of the Z-R (radar reflectivity-rain rate) relationship, which has a number of inherent assumptions and problems. Terrain blocking, anomalous propagation and attenuation of the radar beam, as well as pulse volume sampling of the clouds, all contribute to uncertainties in the precipitation rate and accumulation. These problems will be discussed as they relate to the application of measuring precipitation over the Reynolds Creek Watershed. The instrumented network of rain gauges and meteorological towers at the watershed in the Owyhee Mountains presents a unique opportunity to validate the operational performance of the National Weather Service precipitation rate algorithm. Several winter storms March 1995 are currently under study to assess the performance of the algorithm, and to analyze the applicability of the radar to measuring spatially distributed precipitation in mountainous terrain.

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[8]*David Levinson, Northwest Watershed Research Center, USDA Agricultural Research Service , 800 Park Boulevard, Suite 105, Boise, Idaho 83712*

CAN CHANNEL TYPES BE PREDICTED FROM TERRESTRIAL ECOLOGICAL MAPPING?[9]

The USDA Forest Service and other land management agencies are conducting comprehensive terrestrial and aquatic ecological mapping under the ECOMAP program. Terrestrial and aquatic ecological units are delineated at various scales under hierarchical classifications. Terrestrial and aquatic ecologic maps are the foundations of ecosystem analysis and management. The linkages between terrestrial and aquatic ecological units are of interest primarily in terms of eliciting relationships on the landscape from available datasets. Since aquatic mapping demands considerable personnel time, using terrestrial ecology to predict the occurrence of various channel types is a desirable goal.

In 1998, a terrestrial ecological unit inventory at the landtype level was conducted in the South Creek watershed, a mountainous basin encompassing 15,236 acres, tributary to the Kern River in the southern Sierra Nevada, California. Ecological characteristics mapped were lithology, geomorphology, soils and potential natural vegetation. The perennial stream network was mapped at the reach level using the Rosgen system of stream classification. Riparian vegetation was mapped as an additional attribute of the aquatic inventory. A GIS analysis was performed to display the distribution of aquatic types within terrestrial ecological units.

Examination of the relationships between terrestrial and aquatic attributes reveals associations between terrestrial geomorphology and channel types. Relationships are most pronounced between extremes of upland geomorphic slope classes and process types, compared with channel slope and entrenchment. Unstable and sensitive channel types are associated with meadows, terraces and landslide deposits in low-gradient terrain dominated by fluvial geomorphic processes. Associations are also seen between soils and channel substrate textures, and between upland and riparian vegetation. Examination of reach slope and drainage area may improve channel type discrimination, as may process-based analysis of channel classification and distribution. Extension of the prediction effort to additional watersheds and further statistical analysis will be employed to test the validity of the observed trends.

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[9]*Fred Levitan, Sierra National Forest, USDA Forest Service, 1600 Tollhouse Road, Clovis, California 93611; Cindy Jeffress and Terry Kaplan-Henry, USDA Forest Service, Sequoia National Forest, 900 W. Grand Ave., Porterville, California 93257*

DEFINING STABILITY: EL TORO CREEK, MONTEREY COUNTY, CALIFORNIA[10]

El Toro Creek drains a 42 square mile (109 km^2) watershed in the Sierra de Salinas of coastal California. Land use in this watershed has included ranching, agriculture, suburban development, and large-scale military operations and road construction on the former Ft. Ord Army Base. Changing land-use practices in the El Toro Creek watershed have greatly influenced the channel morphology, resulting in: aggradation, degradation, lateral movement, and flooding, in addition to riparian corridor degradation. Flooding in the lower watershed during the winter of 1995 drew attention to upstream bank instability. In an attempt to mitigate 1997 highway repairs, a straighter and steeper channel was created in one of the most degraded reaches of El Toro Creek. We suggested that straightening the stream would increase velocity and destabilize downstream reaches. We developed an alternate plan using an approach similar to that outlined by Rosgen. This approach identifies a stable reference reach and its associated parameters of stability including: slope, sinuosity, bankfull and floodprone width and depth, vegetation type and density, and channel and bank substrate. We implemented a design that returned the channel to its course prior to straightening. The resulting slope matched that of the selected reference reach, but we were not able to match width-to-depth ratio, sinuosity, and bank vegetation. A reevaluation of the reference reach after the 1997-98 water year (the wettest in a 150-year record) showed an increased width and decreased sinuosity. Despite major changes observed in the mitigation reach (as presented by West et al., this volume), moderate fluctuations in the reach chosen to define stability emphasize the importance of the concept of a reference reach.

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[10]*Danielle L. Lowry, Steven West, and John Stamm, Institute for Earth Systems Science & Policy, CSU Monterey Bay, 100 Campus Center, Seaside, California 93955*

EROSION OVER TIME FROM FOREST ROADS IN THE OREGON COAST RANGE[11]

Erosion from gravel roads can be an important contribution to the sediment budget of streams in many forested basins. Improved estimates of sediment production from forest roads are important for better management of headwater streams. Measurements were made over three years on 74 plots in Western Oregon to quantify the influence of road slope, cross-drain spacing, soil texture, cutslope height, ditch vegetation, cutslope height, and time following construction on sediment production. All plots were insloped with basalt aggregate and light traffic. Results show that sediment production on freshly constructed or cleared plots varies with the product of length and the square of road slope. Soil texture was also found to be an important factor with plots on a silt loam soil producing 9.3 times as much sediment as plots on a gravelly loam. Ditch vegetation was similarly important, as plots with recently cleared ditches produced 7 times as much sediment as plots with well established vegetation. Variation in cutslope height produced no effect on these plots, but high cutslopes may revegetate more slowly, predisposing them to be problems in later years. In general, plots produced less sediment per unit of rainfall energy in later years. Recovery was dominated by vegetation regrowth, although armoring was also important. It is expected that these observations will be valuable in modifying existing empirical models of sediment production and in validating physically based models

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[11]*Charles H. Luce, USDA Forest Service, Rocky Mountain Research Station, 316 E. Myrtle Street, Boise, Idaho 83702, and Thomas A. Black, USDA Forest Service, Rocky Mountain Research Station, P.O. Box 10266, Eugene, Oregon 97440*

PARADISE CREEK WATER QUALITY RESTORATION ACTIVITIES[12]

Paradise Creek, located in Northern Idaho, flows through the. city of Moscow and the University of Idaho Campus. The watershed encompasses 34.5 square miles with 60% of the watershed in Idaho and the remaining 40% in Washington. The upper portion of the watershed is forested with agriculture dominant through the middle portion. The lower part of the watershed is urban/semi urban as Paradise Creek flows through the cities of Moscow, Idaho and

Pullman, Washington prior to entering the Palouse River. Paradise Creek has been designated a water quality limited stream from its headwaters to the Washington State line. Over the last several years the Idaho Water Resources Research Institute (IWRRI) and the Palouse-Clearwater Environmental Institute (PCEI) have been involved in several water quality enhancement projects on Paradise Creek. These include stream channel enhancement, constructed wetlands, re-vegetation of stream beds and stream channel clean-up activities. Stream channel enhancement projects were designed to mitigate erosion and provide some relief for flooding. The constructed wetlands were designed to assist with treatment of the Moscow sewer plant discharge prior to entering into Paradise Creek. This should help with both nutrient loading and temperature stabilization. A project being initiated this fall involves stream modification to develop sloping banks for erosion control, swales for retention of parking lot runoff for bio treatment prior to entering Paradise Creek and planting of trees and shrubs to provide shade to stabilize temperature. These projects are part of a long term plan seeking to help Paradise Creek meet the TMDL standards established for the strewn. Of specific concern are temperature, turbidity and nutrients. Because Paradise Creek flows into Washington, the stream must meet Class A standards established by the State of Washington. These standards require the stream to be protected for salmonid spawning, primary contact recreation and domestic uses. These uses are not supported for Paradise Creek at the present time. Continued effort in controlling non point sources of contamination and enhance stream quality is necessary to meet the water quality standards for Paradise Creek.

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[12] *Leland L. Mink, Idaho Water Institute, University of Idaho, Moscow, Idaho 83844, and Adam Thornbrough, Palouse Clearwater Environmental Institute, Moscow, Idaho 83844*

WATERSHED MANAGEMENT: THE HISTORY OF THE NEW APPROACH[13]

This poster reviews the historical theories of watersheds and watershed management offered by ecologists and environmental managers as the ideas have evolved over the past century, The poster features quotes which range from the views of John Wesley Powell, to John Muir, Aldo Leopold, George Perkins Marsh and Ian McHarg, among others. These concepts establish the theoretical basis for the study and understanding of watersheds and the environment. These views of watershed management also helped to influence the development of various government departments and national programs for environmental management. The poster highlights certain overall themes of watershed management, which remain constant regardless of the decade in which these theorists were writing, The first, and possibly most important theme is that of the interrelated and interacting processes of nature. Whether the writer had utilitarian motives, or ecologically spiritual ones, the concept of nature as an interconnected set of processes was there, A second theme is that of the watershed being a single unit made up of many parts. This theme stresses that any action taken by man, touching any strand or cord, will have an effect that touches everything else. Repeatedly the writers warned of the unknown consequences of human activity in a watershed, and the impacts that could continue to reverberate throughout. An understanding of the historical roots and evolution of the concept of watershed management, helps us better understand its implementation today.

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[13] *Katherine A. O'Connor., A.I.C.P., Orange County Water District, 10500 Ellis Avenue, P.O. Box 8300, Fountain Valley, California 92728*

USE OF GEOSTATISTICS, REMOTE SENSING, AND GIS IN UNDERSTANDING SOIL MOISTURE VARIABILITY AT VARIOUS SCALES WITHIN THE REYNOLDS CREEK EXPERIMENTAL WATERSHED[14]

Understanding the sources of spatial variability of hydrologic variables and characterizing it at different scales is becoming a common interest among both researchers and resource managers. Soil moisture being a critical factor governing the structure and functioning of semi-arid ecosystems, its characterization over different scales within a watershed would benefit in applications such as assessing cropping impacts, land-atmospheric interactions, vegetation growth patterns and land management decisions. While large scale variability is attributed to various sources such as soil properties, topography, climate, vegetation etc. which may be explained with hydrologic modeling, remote sensing or empirical techniques, smaller scale variability is explained by geostatistical correlation structure. We used geostatistical analysis to describe the spatial variability at the sub-catchment scale (0.1-0.3 square kilometer) and a distributed, Geographic Information Systems (GIS) based hydrologic model to quantify the identified sources of variability at a larger watershed scale (234 square kilometer). Soil Adjusted Vegetation Index (SAVI) values derived from satellite images were used as a measure of vegetative productivity and related to water balance variables obtained from a hydrologic model on a seasonal basis at intermediate scales (e.g., soil mapping units). Hydrologic model results were compared with the field measured soil moisture values to determine the applicability of model over a watershed scale.

The geostatistical analysis of field soil moisture data taken at a grid size of 30.5 m x 61 m within the smaller subcatchments over five sampling dates from April to August exhibited a correlation scale of about 122 - 244 m and a moderate degree of spatial dependence. A higher degree of spatial dependence/ spatial continuity was obtained in the direction parallel to the creek compared to the direction perpendicular to the creek. These results suggested implications for future sampling in a way that grid sampling pattern could be suitably employed with the longer side of the rectangle in the direction of longer spatial continuity (or least variation) of the soil moisture field within the smaller catchments. SAVI and hydrologic model results on transpiration and potential evapotranspiration showed some positive relationship over a growing period for the rangeland plant communities. Model predicted soil moisture values were found to be reasonably well correlated ($r2 = 0.71$) with the field measured values. Our GIS analysis on the model predicted soil moisture values led to an approach for partitioning the variability among climate, soil, topography, and vegetation factors. Overall, precipitation, depth of soil, slope, and aspect were found to be the most important sources of variability of soil moisture at the watershed scale.

Our results provide some useful insights for developing strategies for livestock grazing, erosion and sedimentation control, and water quality based on the distribution and amount of plant production.

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[14]*Kala N. Pandit, Department of Biological and Agricultural Engineering, University of Idaho, and Mark S. Seyfried, Northwest Watershed Research Center, USDA Agricultural Research Service, 800 Park Boulevard, Boise, Idaho 83712*

A ROAD SEDIMENT ANALYSIS TOOL[15]

Increasing pressure on natural resources has made forest land management activities extend into remote mountainous areas. Forest roads are an essential element for forest management. However, forest roads are also a major source of sediment production, which can cause a significant environmental impact on stream ecosystems, including anadromous fish species and water quality. Improved sediment prediction tools would help resolve the conflict of building roads and minimizing environmental impacts. One tool available to forest specialists is the Water Erosion Prediction Project (WEPP) model.

This study used the WEPP model to analyze road sediment from the roads in a timber sale on the Boise National Forest southeast of McCall, Idaho. The outsloped 4.4 km road was divided into 42 sections with an average length of 105 m. To acquire the necessary slope information, a set of engineering drawings and a 1:24,000 topographic map were used. The model predicted that 42,000 kg of sediment was produced annually from the road network. Of this amount 61 kg was delivered annually into the stream system. Most of the sediment (99.9%) was caught on the forest floor because of the long distance from the road to the stream which averaged 390 m. Amount of sediment delivered to the stream depended on road tread gradient, distance from the road to the stream, and forest floor slope at each site. The WEPP model can be a useful tool for analyzing road sediment from road networks.

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[15]*Hakjun Rhee, Forest Engineering, University of Washington, Seattle, Washington; Randy B. Foltz and William J. Elliot, USDA Forest Service, Rocky Mountain Research Station, 1221 S. Main, Moscow, Idaho 83843*

WATER REPELLENT SOILS IN THE NORTHERN ROCKY MOUNTAINS[16]

Questionnaires were sent to National Forest Soil Scientists in the Northern Rocky Mountain region requesting information on their experiences with water repellent soils. The questions were: How frequently have you observed water repellent soils after fires? Under which conditions do water repellent soils most commonly occur? How long do water repellent conditions commonly last? How frequently do you have erosion problems associated with water repellent soils?. Thirteen responses were received. The results indicated that water repellent soils are commonly observed in all soil types in the region and are more pronounced with high severity fires occurring when the soil is dry. Repellency decreases after light intensity fall rains. During high intensity rain events increased overland flow causes most erosion to occur in concentrated flow paths.

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[16] *R. Robichaud, USDA-Forest Service, Rocky Mountain Research Station, 1221 S. Main, Moscow, Idaho 83843, and G. Ford, USDA-Forest Service, Idaho Panhandle National Forest, 3815 Schreiber Way, Coeur d Alene, Idaho 83814*

FLOOD RESPONSE IN THE MIDDLE FORK WILLAMETTE: LESSONS OF HISTORY[17]

In November 1996, a 25 year flood event occurred in the headwaters of the Willamette River in the Western Cascade Mountains of Oregon. Channel response included bank erosion, channel abandonment and formation, bar enlargement, and woody debris recruitment. The Forest Service subsequently applied for and received funding to repair flood damage. The need to understand the nature of the damage produced by a flood of this magnitude led to a study of historic channel conditions, processes, and management impacts. Results of the study provide the basis for a rehabilitation project currently underway. Data presented include a 100 year sequence of annual floods, an airphoto sequence beginning in 1936, a detailed USGS map mid longitudinal profile from 1914, and historic fish habitat survey data from 1937. Old salvage records, maps, and photos document previous “flood projects” in the river. This information is compared to recent data including longitudinal profiles (before and after the 1996 flood), fish habitat surveys, pre and post-flood snorkel counts, and recent airphotos.

Conclusions indicate the river’s response to the recent flood is within the range of natural variability for this very dynamic system. While localized “damage” did occur, the ’96 flood also renewed vital features and processes in the river, Rehabilitation efforts are addressing specific effects related to previous management actions.

[17] *Val Rogers, Middle Fork District, Willamette National Forest, Oakridge, Oregon 97463*

RESEARCH APPLICATIONS OF LONG-TERM CATCHMENT INFORMATION: REYNOLDS CREEK EXPERIMENTAL WATERSHED, IDAHO, USA[18]

Analysis of water resources systems relies upon numerical data sets and simulation models to understand system processes, relationships and responses. Rapidly developing techniques and tools of data acquisition and processing hydroinformatics allow enhanced utilization of archival data sets and improved design and implementation of new hydrologic programs. Long-term, quality-controlled data remain invaluable to hydrologic analysis. Such data are available in a sustained (>30 years) whole-catchment data acquisition, archival and analysis research program for a complex-terrain basin in northwestern North America: the 234 km2 Reynolds Creek Experimental Watershed (RCEW) in Idaho, USA. The RCEW research program includes state-of-the-art in situ data acquisition (16 dual-gauge shielded/unshielded precipitation sites, nine continuous streamflow monitoring sites, seven snow courses, three comprehensive climate stations, newly-available NEXRAD doppler radar-derived spatial precipitation data, and multiple ancillary or shorter-term parameter measurements) and radio-telemetry to a central computer archive, automated initial quality control protocols, and immediate availability of data in a variety of formats digital files, graphical displays, spread sheets. The comprehensive RCEW field program provides a framework and context for detailed hydrologic and hydraulic process research, model development and validation. An example is provided in current research to link upland basin hydrologic regime with channel hydraulics; one goal is to elucidate the influence of headwaters streams on lower reaches of the Snake and Columbia River system. Utilizing RCEW s detailed hydrologic record and newly-acquired channel surveys, we demonstrate that typically available low-resolution channel/valley geometry information is inadequate to support application of a widely-used hydraulic model in this high-energy headwaters stream system. High-resolution physical data are necessary to adequately describe even such simple characteristics as stream length, energy slope, and roughness. Coupling detailed physical descriptive data with long-term hydrologic data allows evaluation, application and validation of concepts and models in this headwaters environment, and leads to improved understanding of upland stream systems.

[18] *Charles W. Slaughter, Northwest Watershed Research Center, USDA Agricultural Research Service, 800 Park Boulevard, Boise, Idaho 83712; Peter Goodwin and Rick Marbury, Eco-hydraulics Research Group, University of Idaho, 800 Park Boulevard, Suite 200, Boise, ID 83712*

LANDSLIDES AND LAND USE MANAGEMENT: VALIDATION AND APPLICATION OF A DIGITAL TERRAIN MODEL FOR ASSESSING AND MITIGATING SHALLOW LANDSLIDE HAZARDS[19]

Evaluation of potential mass wasting hazards is a key component of watershed analysis. In many areas, such as the Cost Range of northwestern California, shallow landslides may constitute a significant source of sediment to river ecosystems, particularly after road construction and timber harvesting. A key to successful ecosystem management and sustainable timber harvesting is the identification of potential sediment hazards, such as shallow landslides, and the development of appropriate protection measures to prevent or minimize increased sedimentation caused by land management activities. Stillwater Sciences and the University of California at Berkeley developed an approach that relies on the use of a digital terrain model, or DTM, (the SHALSTAB model developed by William E. Detrich, University of California at Berkeley, and David Montgomery, University of Washington) to identify areas that have a high predicted potential for shallow land sliding. SHALSTAB couples a DTM with a cohesionless, infinite slope stability model and a simple steady state shallow subsurface flow model to predict areas at risk for shallow landsliding. This model has been tested with good success in clear-cut areas in Oregon and Washington, and is now being used by Weyerhaeuser, the Bureau of Land Management (Eugene District), and the Mendocino Redwoods Company to facilitate watershed analysis.

SHALSTAB is integrated into a larger modeling framework for regional watershed analysis and forest ecosystem management, which was developed by VESTRA Resources. This approach is being used to develop Sustained Yield Plans and multi-species Habitat Conservation Plans for over 350,000 acres of forest lands in northern California. This poster describes preliminary results of a study to validate the use of effective means of identifying areas with high shallow landslide hazard potential on a regional basis. Additional studies are currently underway to test the model in a variety of watersheds in Mendocino and Humboldt counties.

[19]*Stillwater Sciences, 2532 Durant Ave., Berkeley, California 94704*

EFFECTS OF THE 1998 EL NINO STORMS ON EL TORO CREEK, MONTEREY COUNTY, CALIFORNIA[20]

The largest storm season of record in California occurred during the 1997-98 rain year (July 1-June 30) and was associated with an El Nino event. In the central coast of California the climate station at Monterey recorded 47.15 inches of total rainfall which exceeded the normal (19.41 inches) by 27.74 inches. We monitored the response of a nearby stream, El Toro Creek, to the 1997-98 event. We estimate that daily mean discharge reached approximately 300 cfs before destroying the USGS gaging station on January 13, 1998. Instantaneous discharge may have been twice this amount. For example, on March 2, 1983 (also during an El Nino event) the daily mean discharge in El Toro Creek was 390 cfs and instantaneous discharge reached 630 cfs. The channel response to the 1997-98 event included severe bank erosion, degradation and aggradation downstream of the gage. This downstream reach had been previously surveyed as part of a bank-erosion mitigation effort (as presented by Lowry et al,, this volume). Cross sections, scour chains, erosion pins, and photo points were established/installed in this reach of El Toro Creek by October 1997. We present the response of El Toro Creek to the 1997-98 El Nino event. For example, our data indicate that stream slope increased from 0.0054 to 0.0070 and cross sectional data indicate that the right bank eroded back 128 ft.

[20]*Steven T. West and John Stamm, Institute for Earth Systems Science & Policy, CSU Monterey Bay, 100 Campus Center, Seaside, California 93955*

MORPHOLOGICAL DESCRIPTION MAIN STEM OF THE UMATILLA RIVER FOR TMDL DEVELOPMENT AND MONITORING[21]

The Umatilla River has been proposed for listing under Oregon’s 303d list of impaired waters for excess sediment. The process of establishing TMDL standards has been undertaken by a coalition of private interests and governmental agencies. As part of this process, we are quantifying current sediment loads and the related watershed attributes. One of the attributes, stream morphology, affects flow quantity, quality, and timing. We propose that modification of some current land use practices will result in desirable changes to stream morphology. These changes might require decades or centuries to occur. These changes will not be recognized unless current conditions are identified and recorded. Thus, we are characterizing reaches in the main stem of the Umatilla River using the Rosgen Stream Channel Classification System and establishing sites to monitor stream bank stability. In this process, we are identifying reaches that have high potential for change. These reaches will be the first to respond to upland and streamside management and should be the focus of future monitoring efforts. Classifications have been made on reaches within the center one-third of the river. Based on these classifications, the potential for an improvement in the hydrologic condition of the Umatilla River ranges from poor to excellent. We are developing plans to classify many of its tributaries using the same methodology.

[21]*John D. Williams, USDA-ARS, Columbia Plateau Conservation Research Center, P.O. Box 370, Pendleton, Oregon 97801; Caty F. Clifton, USDA-FS, Umatilla National Forest, 2517 S.W. Hailey Avenue, Pendleton Oregon 97801; Jim Webster, Confederated Tribes of the Umatilla Indian Reservation, P.O. Box 638, Pendleton Oregon 97801, and Ron W. Rickman, USDA-ARS, Columbia Plateau Conservation Research Center, P.O. Box 370, Pendleton, Oregon 97801*

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Short Course Agenda

Eco-Hydraulics and Physical Processes in Watershed Management

Organizer: *Peter Goodwin, Eco-Hydraulics Research Group, University of Idaho, 800 Park Boulevard, Suite 200, Boise, Idaho 83712 pgoodwin@uidaho.edu in collaboration with IHE-Delft, the Netherlands, Danish Hydraulic Institute, USDA ARS Northwest Watershed Research Center, USFS Rocky Mountain Research Station and Idaho Water Resources Research Institute.*

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October 19, 1998

WELCOME, INTRODUCTION AND SESSION CHAIR

Dr. Howard Peavy, Associate Dean, College of Engineering, University of Idaho

THE IMPORTANCE OF UNDERSTANDING PHYSICAL PROCESSES IN WATERSHED MANAGEMENT

Professor Tom Dunne, School of Environmental Management, University of California, Santa Barbara

Description of the significant physical processes in watersheds illustrated by case studies.

WATERSHEDS AS POPULATIONS OF ELEMENTS OVER TIME: IN PURSUIT OF FREQUENCY DISTRIBUTIONS OF ENVIRONMENTAL STATES

Dr. Lee Benda, Earth Systems Institute, Seattle, WA.

Episodic climatic and geomorphic processes (wildfires, landslides, sedimentation, and channel changes) reflect system properties of landscapes. System refers to the out come of the collective behavior of populations of forest stands, hillslopes, and stream channels over time. The collective behavior is represented by characteristic frequencies and magnitudes of landscape forms and processes. Frequency distributions of environmental states, which emerge only at large spatial and temporal scales, could be integrated into watershed management, including defining natural disturbance and cumulative effects.

HOW TO CHARACTERIZE CONTROLS ON WATERSHED PROCESSES

Dr. Dan Miller, Earth Systems Institute, Seattle, Washington

To assess watershed condition, and to anticipate change, requires that the physical factors controlling watershed processes be identified and quantified at the temporal and spatial scales over which interactions occur to create the watershed environment.

Likewise, environmental attributes must be characterized at the scales over which a change in the controlling factors will produce a quantifiable environmental change.

Session chair: Dr. Vladan Babovic, Danish Hydraulic Institute

THEORY AND PRACTICAL APPLICATIONS OF BED LOAD TRANSPORT

Dr. Alan Barta, USFS Rocky Mountain Research Station, Boise, Idaho

Review of bed load transport theory and modeling with applications to sediment budgeting and TMDLs.

HYDROINFORMATICS - INFORMATION TECHNOLOGY FOR WATERSHED MANAGEMENT

Dr. Anthony W. Minns, IHE-Delft, The Netherlands

The rapid increase in the capacity of modern computers has opened up a new world of methodologies for mathematical modeling. The complex and sometimes bewildering derivations and solution algorithms for empirically based, ordinary and partial differential equations have long been the domain of computer-based, hydraulic calculations, or 'computational hydraulics'. These new modeling approaches and the integration of IT with conventional hydrologic and geomorphic models will be described.

Session chair: Dr. Anthony W Minns, IHE-Delft

MODELING SALMONID POPULATIONS AT THE WATERSHED SCALE

Dr. Danny Lee and Dr. Bruce Rieman, USFS Rocky Mountain Research Station, Boise, Idaho

Explanation of recent and ongoing work to predict population responses to landscape attributes and past land management.

INDIVIDUAL-BASED APPROACH TO ECOLOGICAL MODELING

Dr. Vladan Babovic, Head, Emerging Technologies, Danish Hydraulic Institute, Copenhagen

The complexity of an ecological system arises from the multiplicity of details. During the last ten years a novel and alternative individual-based approach has emerged. The models are based on individual organisms rather than on populations of more highly aggregated state variables. Individual-based models allow ecological modelers to investigate types of questions that have been difficult or impossible to address using the state-variable approach. Various case studies will also be summarized.

3:00-3:15 BREAK AND COMPUTER DEMOS

Session chair: Dr. Roy Mink, Idaho Water Resources Research Institute

PROCESSES IN SMALL HEADWATER CATCHMENTS - SNOW, FIRE, STEEP GRADIENTS, SEDIMENT TRANSPORT, DEVELOPMENT

Dr. Charles W. Slaughter, USDA ARS Northwest Watershed Research Center, Boise, Idaho

Experiences and knowledge from 30 years of detailed monitoring at the Reynolds Creek watershed.

SELECTION OF APPROPRIATE MODELING AND SIMULATION TOOLS

Dr. Peter Goodwin, Eco-hydraulics Research Group, University of Idaho, Boise

The different types of computer models available for predicting flows and sediment transport in river channels will be presented. Case studies from Europe and the United States will be used to illustrate the importance of selecting an appropriate model formulation for environmental river management and floodplain restoration projects.

COURSE CLOSURE

Dr. Anthony W. Minns, IHE-Delft, and Dr. Roy Mink, Idaho Water Resources Research Institute, University of Idaho, Moscow

FIELD TRIPS

BOISE FRONT AND 8TH STREET FIRE REHABILITATION

Organizer: *Dr. Fred Pierson, USDA ARS Northwest Watershed Research Center, Boise, Idaho*

In late August, 1996, a wildfire swept across the foothills above Idaho s capitol city of Boise. The 12,000 acre area commonly known as the Boise Front was completely burned, from the city s edge to the crest of the mountains. Following what became known as the 8th Street Fire, land treatments ranging from shallow ripping to intensive trenching were applied across the Boise Front to reduce the susceptibility of the site to severe runoff and erosion. Small flood control structures were built at the bottom of main tributaries to control runoff and store sediment and debris.

A tour of the Boise Front two years following the fire was offered on Thursday afternoon of the Workshop. Leah Juarros, Boise National Forest, explained the implementation and utility of contour trenches, contour felled logs, hand-dug trenches and aerial seeding treatment applications. Fred Pierson, USDA-ARS Northwest Watershed Research Center, explained research results from a rainfall simulation study which identified key areas of the watershed particularly susceptible to runoff and erosion damage. Paul Seronko, BLM Boise District Office, provided information relative to the use of straw wattles and tractor seeding treatments at the lower elevations. He also talked about road drainage, sensitive plant and noxious weed issues. The tour concluded at the bottom of the hill where Chuck Mickelson, City Engineer for the City of Boise, addressed the design and construction of catchment basins at the mouth of each of the gulches leading into downtown Boise.

REYNOLDS CREEK EXPERIMENTAL WATERSHED, OWYHEE MOUNTAINS

Organizer: *Dr. Mark Seyfried, USDA-ARS Northwest Watershed Research Center, Boise, Idaho*

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 woodlands of the interior Pacific Northwest. RCEW is operated by the Northwest Watershed Research Center, USDA Agricultural Research Service.

The 234 km2 watershed, selected to represent a broad suite of rangeland characteristics, is located in the Owyhee Mountains of southwestern Idaho. Reynolds Creek is a northward-flowing third-order perennial stream that drains directly into the Snake River, a major tributary of the Columbia River. RCEW ranges in elevation from 1100 m to 2250 m. 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 hay production in the lower valley and minor timber harvest in high-elevation forests. RCEW is widely utilized for summer and winter outdoor recreation. Annual precipitation varies from about 23 cm at the northern lower elevations to over 100 cm (ca. 75% as snow) in the high-elevation southern and southwestern watershed sectors.

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. Plant communities are typical of the semi-arid northern Great Basin: Wyoming big sagebrush; mountain big sagebrush ; low sagebrush; curleaf mountain mahogany; bitterbrush; bluebunch wheatgrass/Sandberg bluegrass; Idaho fescue/bluebunch wheatgrass. Forest stands at the highest elevations include subalpine fir, Douglas fir and quaking aspen woodland.

The research program has emphasized rangeland hydrology, precipitation, climate, seasonal snowpack accumulation and melt, seasonally frozen soils, and streamflow, soil erosion, and stream sediment processes. Detailed meteorological measurements are collected hourly at three sites (low, mid 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 in the Reynolds Creek valley. Hydrologic monitoring includes state-of-the art data acquisition, real-time telemetry from all field sites, and relational data base archiving. Research at the Northwest Watershed Research Center and RCEW supports improved understanding of hydrologic processes and relationships, which in turn should enhance the ability of managers to develop improved management plans and prescriptions for specific rangeland settings.

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