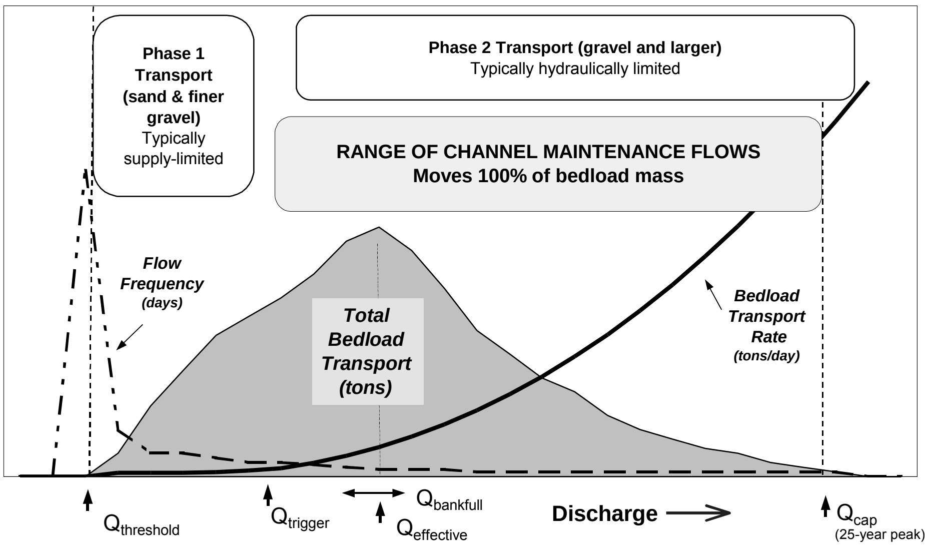
Volume 1

A General Model of Sediment Transport Processes for Channel Maintenance in Gravel-Bed Rivers



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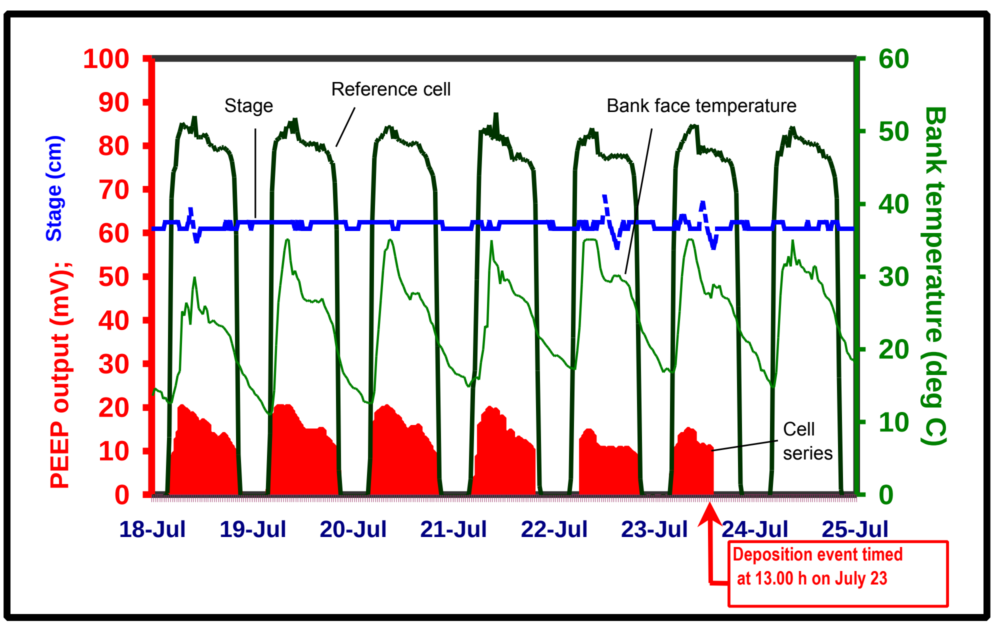

POSTERS

Posters

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STREAM CUTBANK EROSION IN CENTRAL NEVADA STREAMS

By M. C. Amacher, Research Soil Scientist, USDA Forest Service, Logan, Utah; J. Kotuby-Amacher, Director of USU Analytical Labs, Utah State University, Logan, Utah

Abstract: Bare cutbanks with near vertical faces are sources of sediment transported in some deeply incised stream channels in the Toiyabe Range in central Nevada. To monitor rates of cutbank erosion, several sets of erosion pins were installed in exposed cutbanks along San Juan and Marysville Creeks and the exposed length of each pin was measured annually from 1996 to 1999. More cutbank erosion was observed in 1998, a high-water year, than in 1997 or 1999, which were drier years. Cutbanks in lower reaches of the drainages, where channel incision was deeper, had greater rates of erosion than cutbanks in upper reaches of the drainages. Gravitational failure of cutbanks adjacent to or near the active stream channel provides a ready supply of non-cohesive material on toeslopes lacking vegetation that is available for transport by basal cleanout during episodic events or high-water years.

INTRODUCTION

Many streams in the Toiyabe Range of central Nevada are deeply incised because 1) not enough sediment has been delivered from uplands to stream channels to balance sediment outflow, 2) stream gradients and flow during high-water events are high enough to transport large amounts of bedload resulting in streambed degradation, and 3) streambed sediments and streambank soils adjacent to active channels are highly erodible. Erodibility is influenced by physical and chemical properties of the streambed sediments and streambank soils including particle size distribution and the presence or absence of cementing agents such as carbonates. Within a given drainage, incision is influenced by geomorphic position, stream gradient, streambed and streambank particle sizes, and type and density of vegetative cover (Chambers et al., 1998). Currently, side valley alluvial fans are acting as base level controls within several central Nevada drainages. Amount and rate of channel incision is largely controlled by a stream's ability to cut through the coarse-grained side valley fan deposits (Chambers et al., 1998).

As a result of channel incision, numerous cutbanks with near vertical faces of bare soil and parent material of older alluvial deposits are found along the more deeply incised stream channels. These cutbanks may be found adjacent to the active channel or separated from the active channel by stream terraces and floodplains. Toeslopes of unconsolidated material eroded from the cutbanks are found at the bases of many of the cutbanks. Recently formed toeslopes lack vegetation.

During high-water years, frequent and prolonged precipitation events during the spring combined with melting snowpacks from heavy snowfall winters cause flood events resulting in more channel incision. Such a high-water event occurred in central Nevada in 1995 and again in 1998. Most of the sediment transported in stream channels during these high-water years was transported as bedload. Streams differed greatly in the amounts of sediment transported, which appeared to be related to sediment supply. Sources of transported sediment included the streambed, bare cutbanks, roads, and uplands. On-site observations during the high-water events indicated that the streambed and the cutbanks were major sources of transported sediment. Post-event stream channel cross-section measurements revealed deeper incision of the active stream channels at many locations (Chambers et al., 1998).

O'Neill and Kuhns (1994) summarized the mechanisms of streambank erosion. These include wedge, popout, and cantilever failure as a result of gravitational forces and undercutting, bed degradation, and basal cleanout as a result of tractive forces from stream flow. Field observations indicated that these processes are operating on cutbanks in central Nevada streams. Although channel cross-sections provide an effective monitoring tool for documenting changes in channel morphology with time, they are limited if detailed information is needed about erosion of cutbanks in which large changes in vertical distance occur over very short horizontal distances. Furthermore, features such as popout failure and undercutting are difficult to quantify using channel cross-sections. Therefore, erosion pins, which are more suited for studying erosion of cutbanks with near vertical faces, were used to quantify rates of cutbank erosion in two deeply-incised central Nevada streams.

METHODS

Several sets of erosion pins were installed in 1996 in bare cutbanks along San Juan and Marysville Creeks in the Toiyabe Range of central Nevada. Additional sets of pins were installed in 1997 and 1998. Each pin was a 0.25-in diameter steel welding rod 3 ft in length. At each selected cutbank, a set of pins was installed by hammering the pins into the bank at selected distance intervals measured from the top of the bank to the top of the toeslope at the base of the bank. The pins were installed horizontally (perpendicular to the bank face) and a small section of each pin length was left exposed. The exposed length of each pin at each vertical distance was measured after the pins were installed and again each year (1997, 1998, and 1999) during the summer after peak flow. Both annual and cumulative loss or gain in cutbank horizontal distance measured at each pin was plotted against vertical distance from the top of the bank to the toeslope. Box plots of annual loss or gain of cutbank soil at each site and for each year within San Juan and Marysville Creeks were prepared.

RESULTS AND DISCUSSION

The cumulative loss or gain of soil from a cutbank along San Juan Creek and another along Marysville in 1997, 1998, and 1999 are shown in Fig. 1 as examples. Most of the cutbanks showed little erosion from 1996 to 1997, a low-water year in central Nevada. Some minor popout failure was observed at many of the cutbanks as shown in Fig. 1. Greater amounts of cutbank erosion were observed in 1998, a high-water year, and the results shown in Fig. 1 were typical of cutbanks that had high rates of erosion. Not all cutbanks had this much soil loss. Many had little erosion in any of the three years observed to date. At San Juan site 4 (left side of Fig. 1), the upper portion of the cutbank had eroded away along the entire length of the erosion pins by 1999. A more stable section of the cutbank remained, but it is severely undercut (bottom of left side of Fig. 1), and will eventually fail. At Marysville site 5, soil lost from the upper section of the cutbank was deposited at the base of the cutbank, thus expanding the toeslope and covering portions of the lower erosion pins (right side of Fig. 1).

Box plots of annual loss or gain of cutbanks from 1996 to 1999 at 14 sites along San Juan Creek are shown in Fig. 2. Sites 4, 5, and 6, which are in the most deeply incised reaches in the lower part of the San Juan Creek drainage, had the highest rates of erosion during the three year period observed. At sites where the cutbank is separated from the active channel by a stream terrace, soil lost from the upper part of the bank was deposited on an expanding toeslope at the bottom of the bank. Thus, erosion pins in the upper part of the cutbank became more exposed with time, while erosion pins in the lower part of the cutbank were covered as the toeslope expanded. Most cutbanks showed a net loss of soil from 1996 to 1999, however. The toeslopes generally consist of loose unconsolidated material and show little vegetation recruitment. Toeslopes on the youngest floodplain are more susceptible to basal cleanout than those separated from the active channel by an older stream terrace. These toeslopes would only be subjected to basal cleanout in the most extreme flood events.

Box plots of annual loss or gain of cutbanks from 1997 to 1999 at 10 sites along Marysville Creek are shown in Fig. 3. As at San Juan Creek, most of the cutbank erosion was found in the more deeply incised lower reaches of the stream. Where not removed by basal cleanout during the 1998 high-water year, soil lost from the upper part of the cutbanks was deposited on toeslopes at the base of the banks.

Box plots of annual loss or gain of cutbanks in 1997, 1998, and 1999 at all sites in San Juan and Marysville Creeks are summarized in Fig. 4. Erosion of cutbanks along both streams was similar in 1997. In the 1998 high-water year, more erosion of cutbanks was observed in San Juan than in Marysville Creek. Losses from the upper parts of the Marysville cutbanks were balanced by gains along the cutbank toeslopes. Basal cleanout in 1998 was greater in San Juan Creek than in Marysville. San Juan Creek had higher peak flows than Marysville Creek in 1998 (1.2 vs 0.7 m^3/s, respectively) and the cutbanks in San Juan are more erodible. In 1999, high levels of cutbank erosion continued in San Juan Creek, but because stream flow was much lower that year, toeslopes at the bases of the cutbanks expanded. This material is now available for basal cleanout during future high-water events.

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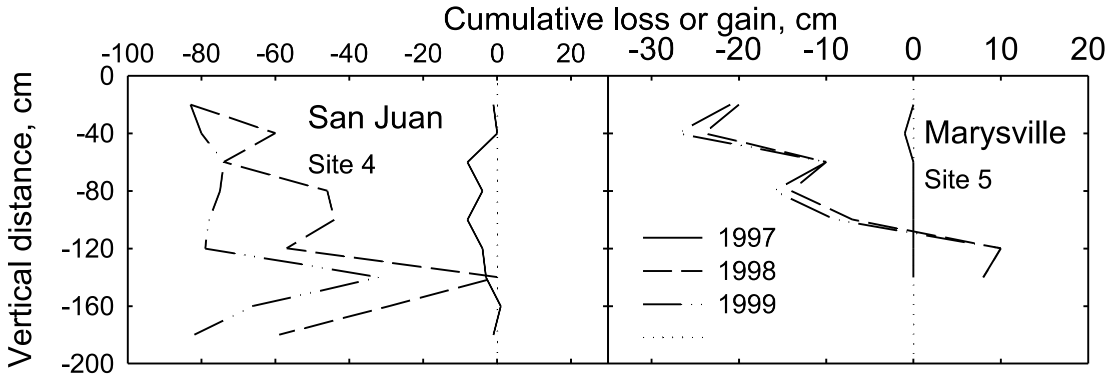

Fig. 1. Cumulative loss or gain in cutbanks at two sites along San Juan and Marysville Creeks.

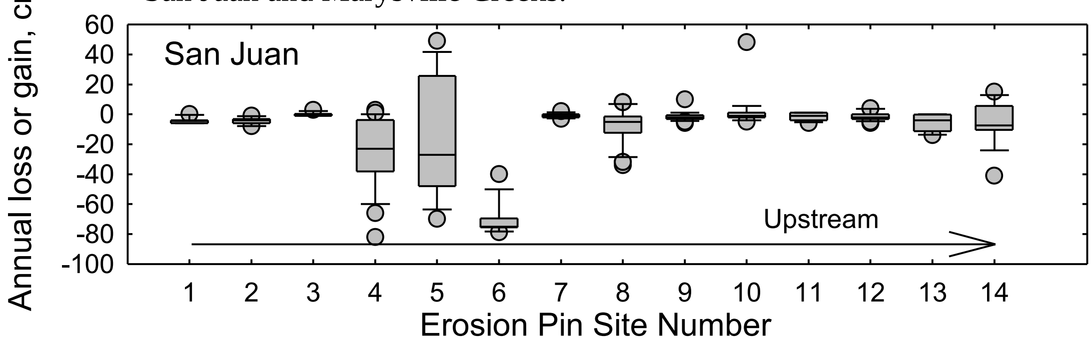

Fig. 2. Box plots of annual loss or gain in cutbanks at 14 sites along San Juan Creek from 1996 to 1999.

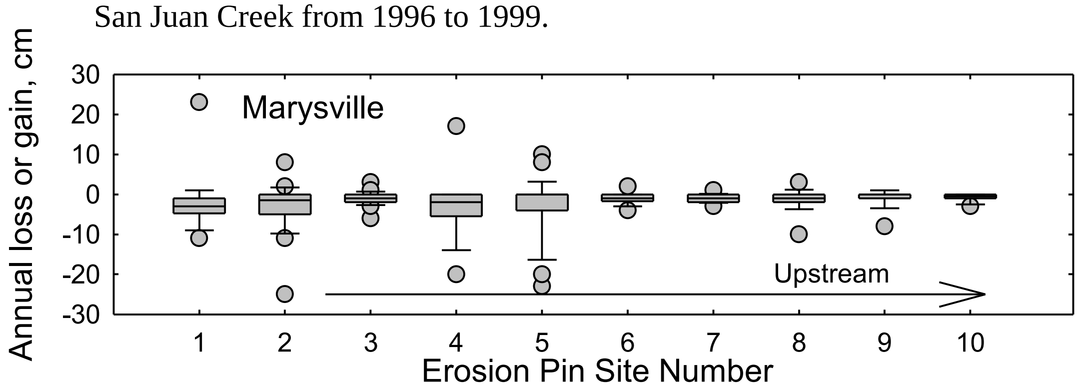

Fig. 3. Box plots of annual loss or gain in cutbanks at 10 sites along Marysville Creek from 1996 to 1999.

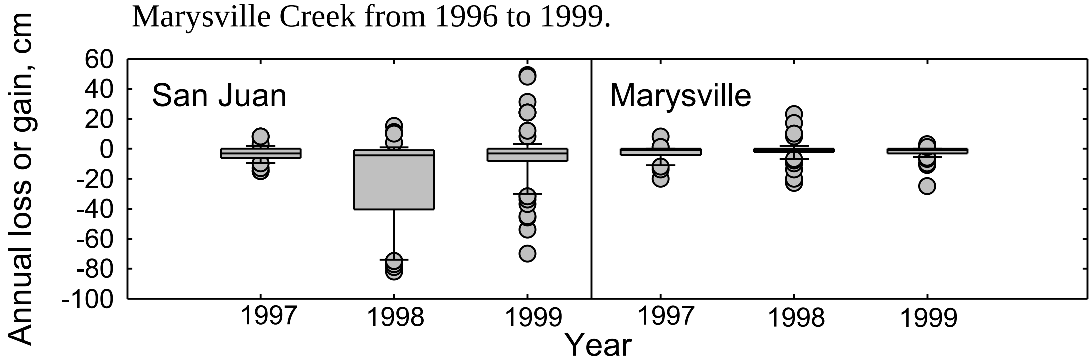

Fig. 4. Box plots of annual loss or gain in cutbanks at all sites along San Ju and Marysville Creeks in 1997, 1998, and 1999.

ABSTRACT

RESTORING NATURAL PROCESSES IN ALLUVIAL MEADOW SYSTEMS.

Presented by: Terry Benoit, Jim Wilcox, and Bob Schultz, US Forest Service, P.O. Box 11500, Quincy, CA 95971. (530) 283-7822 or email at tbenoit@fs.fed.us.

Through the restoration of several meadow systems, techniques are being developed that return previously degraded meadow systems to near their former hydrologic and hydraulic conditions. The biological components rapidly recover to desirable states.

STREAM CORRIDOR RESTORATION
Principles, Processes, and Practices

ABSTRACT

Jerry M. Bernard, National Geologist
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The subject document is "Stream Corridor Restoration: Principles, Processes, and Practices" and is one of the technical bases that many US Federal agencies are using to restore engineering and ecological functions to streams in the United States.

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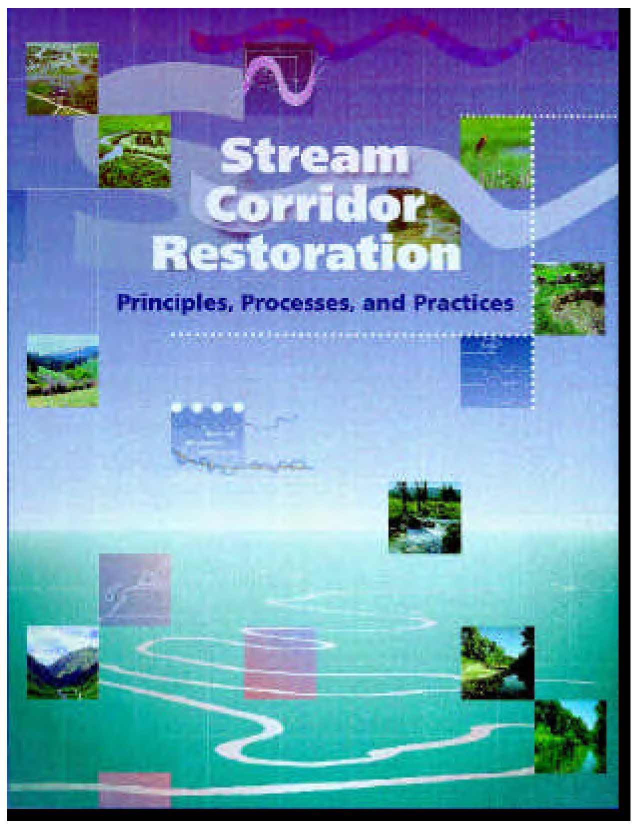

Why "stream corridor restoration"?

There's more to a stream than the rushing or meandering water. A stream corridor, or stream valley, is a complex and valuable ecosystem which includes the land, plants, animals, and network of streams within it. Recognition of the value of stream corridors has come with the understanding of what has been lost through uninformed or misguided actions on many streams and the watersheds that nourish them.

The U.S. has 3.5 million miles of rivers. The 1992 National Water Quality Inventory of 642,881 miles of these rivers stated that only 56 percent fully supported multiple uses, including drinking water supply, fish and wildlife habitat, recreation, and agriculture, as well as flood prevention and erosion control. In the remaining 44 percent of stream miles inventoried, sedimentation and excess nutrients were the most significant causes of degradation. Sediment problems result from soil erosion from watersheds and streambanks.

Today, interest in restoring stream corridors is expanding nationally and internationally, as indicated by increasing numbers of case studies, published papers, technology exchanges, research projects, and symposia. Stream corridors are increasingly recognized as critical ecosystems supporting interdependent uses and values.

This document was produced by the collective experience, skills, and technology of 15 Federal agencies of the United States government. It is a benchmark document that is being used by these agencies, as well as many others who are interested in restoring the functions and values of the nation's stream corridors.

Restoration practitioners share simultaneously in the good fortune and responsibility of participating in a new endeavor -- stepping beyond the current concept of natural resources conservation to a newer concept of restoring the living environment to an ecologically viable condition -- to create places that improve rather than degrade over time. Oliver Wendell Holmes once said, "A mind stretched by a new idea can never go back to its original dimension."

This document is a result of an unprecedented cooperative effort among fifteen Federal agencies and partners to produce a common reference on stream corridor restoration. It responds to a growing national and international public interest in restoring stream corridors. Increasingly, feature articles, case studies, and published papers focus on stream corridors as critical ecosystems in our living environment. The recent 25th anniversary of the Clean Water Act also has helped focus attention on stream corridor restoration. This document encapsulates the rapidly expanding body of knowledge related to stream corridors and their restoration. It makes no endorsement of one particular approach to restoration over another; nor is it intended as a policy document of any participating Federal agency. It includes the full range of possibilities facing restoration practitioners, including no action or passive approaches, partial intervention for assisted recovery, and substantial intervention for managed recovery.

A product of the Clean Water Action Plan is the demonstration of stream corridor restoration technology in National Showcase Watersheds (**http://www.epa.gov/owow/showcase/**).

The document encourages locally led, public involvement in restoration planning and implementation. The challenges in restoring thousands of miles of degraded stream corridors must involve the participation of government agencies, public and private landowners, permit holders, and local volunteer, civic, and conservation groups and individuals. We encourage users of this document to supplement it with new literature, and regionally or locally specific information. We encourage restoration practitioners to share new information and case studies with others to advance the art and science of stream corridor restoration.

The Federal Stream Restoration Working Group

United States Department of Agriculture
- Agriculture Research Service
- Cooperative State Research, Education, and Extension Service
- Forest Service
- Natural Resources Conservation Service

United States Department of Commerce
- National Oceanic and Atmospheric Administration National Marine Fisheries Service

United States Department of Defense
- Army Corps of Engineers

United States Department of Housing and Urban Development

United States Department of the Interior
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- Bureau of Reclamation
- Fish and Wildlife Service
- National Park Service
- United States Geological Survey
  - Biological Resources Division
  - Water Resources Division

United States Environmental Protection Agency

Federal Emergency Management Agency

Tennessee Valley Authority

THE SEDIMENTATION MESSAGE

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How does communication fit with sedimentation? Neatly, if you or your organization is prepared to communicate the story of sedimentation to a targeted audience beyond the scientific or professional. Why? Primarily because private landowners control 70% of the land and 80% of the water in the United States. Without their cooperation, the issues surrounding sedimentation will not be addressed and cannot be solved.

Let's look at a basic concern. How many people truly understand or care about sedimentation? Probably not many, except those few who are scientists, planners, or conservationists. <u>If</u> that is true, how do you get your work made known to the populace in general? Maybe you don't want to. That, in itself, is a communication decision. If you do, though, who is the intended audience, and what do you want them to do? And why? What motivations do they have that match the intended outcomes of a communication strategy?

This poster session will look at sedimentation from the receiver's viewpoint and will help you identify methods to engage citizens through a planned communication program.

#############

ABSTRACT

AGNPS 98: A suite of water quality models for watershed analysis.

Presented by: Ron Bingner, Agricultural Engineer, USDA-Agricultural Research Service, National Sedimentation Laboratory, P.O. Box 1157 McElroy Drive, Oxford, MS 38655, phone 662-232-2966, fax 662-232-2915, email bingner@sedlab.olemiss.edu.

This poster will describe and demonstrate the functionality of AGNPS 98 for use in studying watersheds. AGNPS 98 can be useful in TMDL studies or any area where pollutant loadings need to be evaluated. AGNPS 98 has been particularly developed for USDA-NRCS, but many other organizations will find it useful. Demonstrations of the programs components will be shown during the poster session.

FIELD TRIALS MONITORING SAND DEPOSITION AND EROSION ON A RAZORBACK SUCKER SPAWNING BAR ON THE GREEN RIVER NEAR JENSEN, UTAH, AND OPERATIONAL DESCRIPTION OF LOAD-CELL SCOUR SENSORS

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INTRODUCTION

A liquid-filled, load-cell scour sensor is being used to monitor deposition and erosion on a sand and cobble bar on the Green River in northeastern Utah downstream from Flaming Gorge Dam and the confluence with the Yampa River (fig. 1). The bar is 3 miles downstream from the streamflow-gaging station Green River near Jensen, Utah (09261000), and is used by razorback suckers for spawning in April and May before spring runoff. The monitoring is part of a study of endangered razorback suckers being done by the U.S. Geological Survey, the National Park Service, and the U.S. Fish and Wildlife Service. The load-cell sensor weighs the sediment, water, and air above it, and an accompanying pore-pressure sensor weighs the water and air above it. The difference between the two weights is the weight of the sediment overlying the sensor pair. Combined sensitivity and repeatability are ±0.01 foot of sediment thickness or less. A temperature sensor in the pressure-sensor housing provides useful information about the spawning-bed and sensor environment and enables calibration of the pressure sensors to ±0.02 percent of full-scale output.

FIELD TRIALS

Seven sensor pairs were buried at depths of 0.3 to 1.5 feet in an array across the bar and the adjacent channel and provide hourly data to a datalogger (figs. 1 and 2). River stage at the spawning bar is determined from the pore pressure sensor at sensor D. The load-cell sensors have documented (1) deposition of as much as 0.7 foot of sediment on the spawning bar during the historically determined spawning period and within the historically determined spawning-temperature range (sensors A and D), (2) subsequent erosion of the deposited sediment, (3) the migration of dunes 0.2 foot in height or less in the channel (sensor F), (4) passage of a cobble, ice, or debris in the bed load with a scour hole in front of and behind the object (sensor D), and (5) ice-dam buildup with ponding of as much as 5 feet over the bar and subsequent erosion or breakup of the ice dam.

DESCRIPTION AND OPERATION

The liquid-load-cell scour sensor consists of a shallow, stamped 10-inch by 6-inch rectangular stainless-steel vessel with 0.002-inch stainless-steel foil that spans the open top and is silver soldered to the perimeter (fig. 3). A stainless-steel pipe fitting is silver soldered into a hole in the end of the vessel. The vessel is filled with degassed water, and the mating pipe fitting, which contains a pressure sensor ported inside the vessel, is attached under water. The load-cell sensor is buried, with the foil surface on top in a horizontal plane, to a depth below anticipated scour. The pressure sensor inside the water-filled vessel weighs the sediment, water, and air above it as that weight is applied to the compliant foil and, in turn, to the relatively incompressible water inside the vessel. A second pore-pressure sensor, ported to the sediment outside the vessel, weighs the water and air above it. The pressure inside the vessel minus the pore pressure outside the vessel is the weight of the overlying sediment or effective stress. A coefficient of about 0.8 times the weight of the sediment gives the sediment thickness. The coefficient is determined by field calibration and accounts for grain density and porosity.

The sensor can be buried or jetted into cohesionless sediment such as a sandbar. The sensor weighs sediment in a cone above it. The cone consists of sediment above the angle of internal friction or angle of repose, about 30 degrees above horizontal. The deeper the sensor is buried, the safer it is from being scoured and the larger the area it averages. The shallower the sensor, the greater the detail that can be determined from closely spaced sensors, but the greater the risk of removal by scour. The small change in grain packing after scour and fill is addressed by periodically resurveying the streambed above the sensor. Recalibration also can be determined in ephemeral streams when the stream goes dry. At that time, the sediment thickness above the sensor is equal to the height of the water column within the saturated sediments from the accompanying pore-pressure sensor to the bed surface. Bridging of grains across the foil, which could prevent the transfer of changes in sediment weight to the sensor, does not appear to be a problem in saturated cohesionless sediment. The sensor also works on its side, with the foil in a vertical

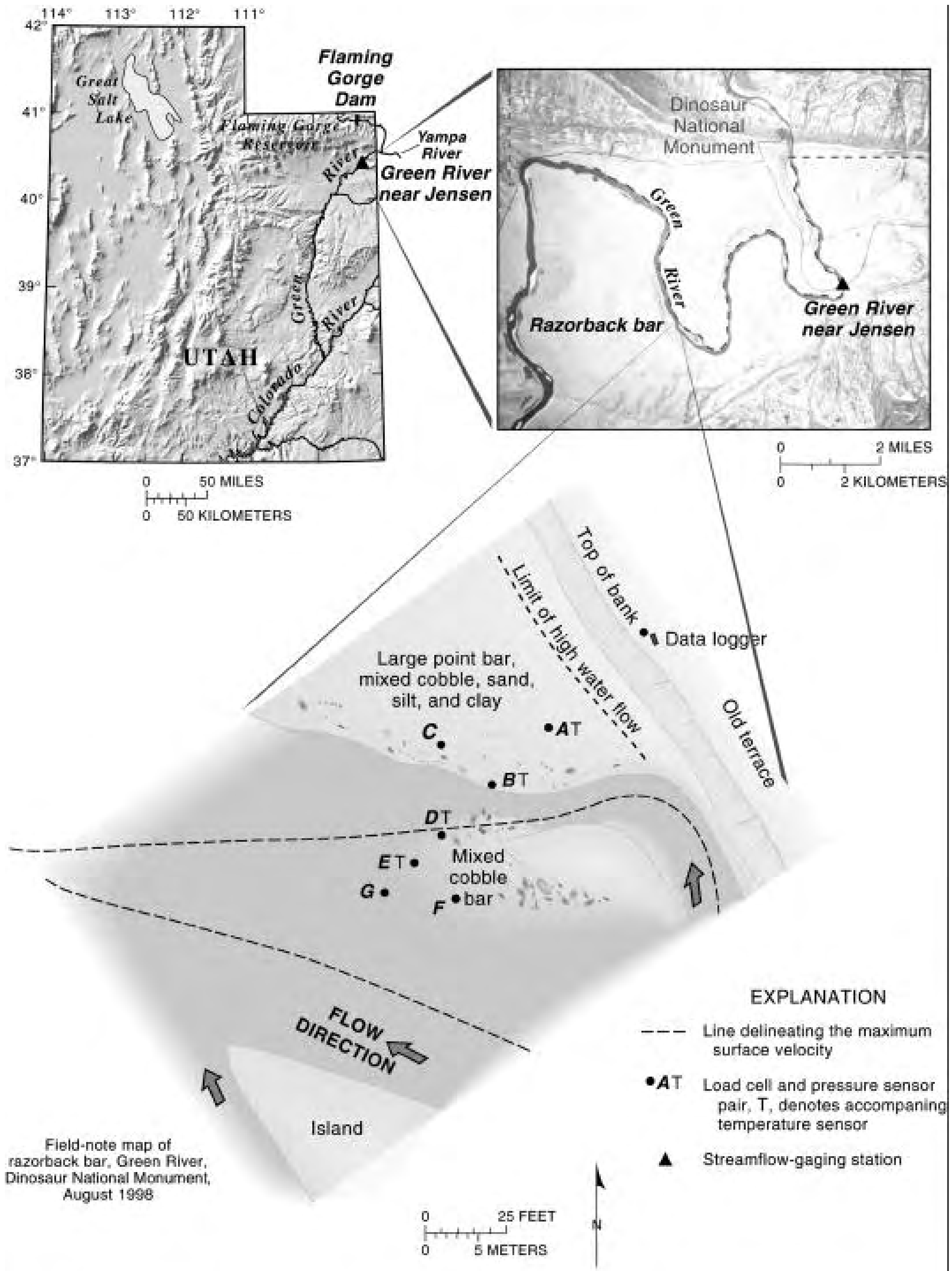


Figure 1. Location of sensors in razorback sucker spawning bar.

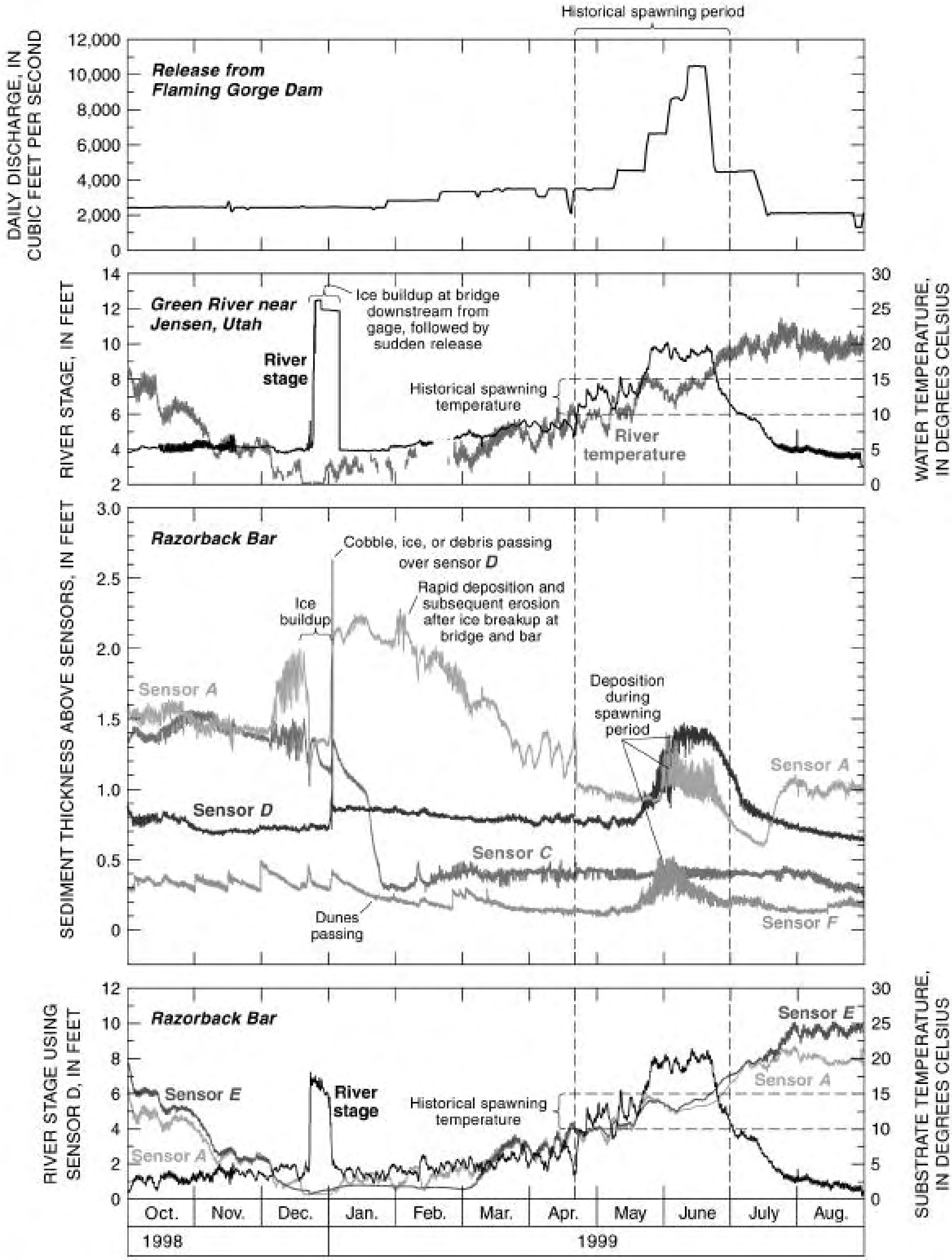


Figure 2. Streambed deposition and erosion, river stage, and substrate temperature at the razorback sucker spawning bar, release from Flaming Gorge Dam, and river stage and water temperature at the Jensen, Utah, streamflow-gaging station (*09261000*).

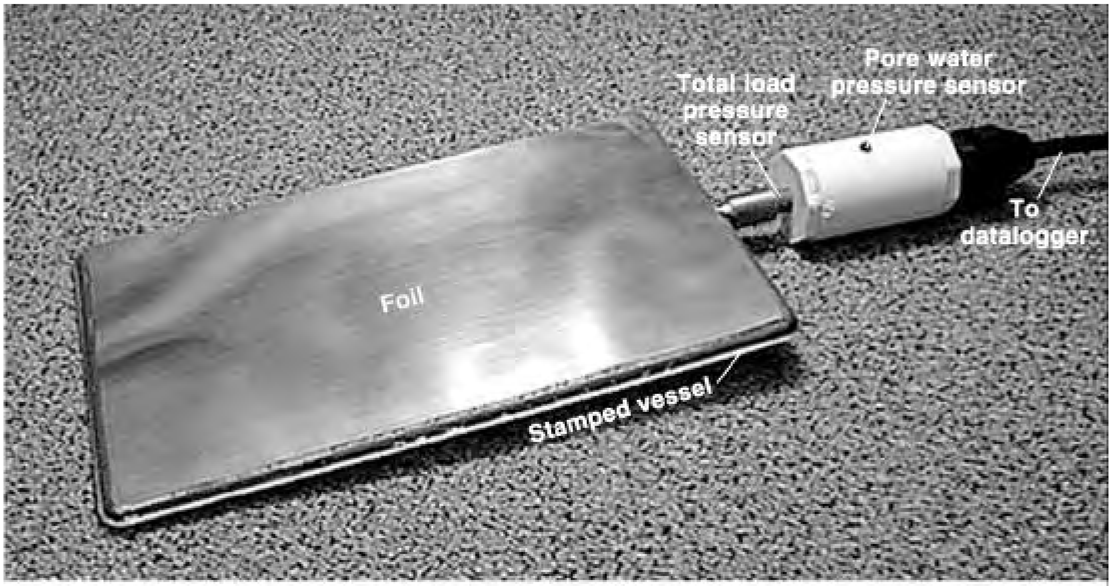


Figure 3. Load-cell scour sensor.

plane, because changes in horizontal stress (with a coefficient of about 0.3) in sediment accompany changes in vertical stress (weight per unit area) that are caused by scour and deposition.

The load-cell sensor can provide unattended measurement and documentation of scour, deposition, and sediment transport in ephemeral streams. Installation of multiple sensors in two or more closely spaced cross sections will enable automated slope-area determinations of discharge and establishment of rating curves at sites in sand channels that are inaccessible during flow. Additional uses of the sensor include scour at bridge piers and similar structures, studies of liquefaction or quicksand, and beach erosion. The load-cell measurement differs from other techniques of measuring scour, such as time-domain reflectometry and sonar, by distinguishing between actual static grain-to-grain contact and near grain-to-grain contact that occurs during liquefaction or quicksand and can occur in saltation transport of bedforms. In the case of liquefaction, both the load-cell sensor and the pore-pressure sensor measure the weight of a dense liquid, namely water with sand grains dynamically suspended in or settling through the water.

TESTING AND PRIOR USE

For the sensor to be useful, the sediment overlying the sensor must transfer a change in weight caused by deposition and erosion to the sensor in a linear, repeatable, and reversible manner. The sensor was tested by being buried at a depth of 5 feet with the water level above and below the bed. Sediment was deposited on and removed from the bed, and a load was placed on and removed from the bed. The associated accuracy and repeatability of the measurement was 0.01 feet. Seven sensor pairs were used to document erosion, deposition, and a sudden scour event on a sandbar downstream from the mouth of the Little Colorado River during the spring 1996 controlled flood experiment on the Colorado River in the Grand Canyon.

INSTALLATION AND PRACTICAL CONSIDERATIONS

Conventional installation requires trenching to a depth below anticipated scour for the electrical cable that extends from the sensor to a buried waterproof box that houses the datalogger on the river bank. In gravel and cobbles having little chance of scour, hand-shovel trenching can be done in approximately knee-deep water. In sand, hand-shovel trenching requires a dry bed. A cylindrical version of the sensor vessel and radio-frequency-modem communication, which are still under development, are intended to make installation possible or easier in flowing sand or where trenching is not possible. The sensor is robust. After the sudden erosion event in the Grand Canyon flood of 1996, the sensors were scoured out and banged against the canyon wall in the current for 2 months. Several of those sensors were subsequently used on the Green River in Utah. The sensors are tested to 30 pounds per square inch and can be buried to a depth of 20 feet with 20 feet of additional submergence. The sensor is sensitive to small changes in sediment load and can measure infilling of gravel and cobbles with fine-grained sediment. Ideal uses for the sensor include (1) shallow placement in spawning beds of fish for unattended monitoring of deposition, erosion, and substrate temperature, (2) monitoring transport of bedforms in experimental flumes, and (3) monitoring scour at bridge piers or similar structures.

INTEGRATION OF THE WEPP AND HEC-6T MODELS TO PREDICT SOIL EROSION AND ACTINIDE TRANSPORT IN SURFACE WATER

By F. Winchester Chromec, Senior Scientist, Rocky Mountain Remediation Services, Rocky Flats, Colorado; Gregory A. Wetherbee, Environmental Scientist, Wright Water Engineers, Denver, Colorado; Ian B. Paton, Environmental Engineer, Wright Water Engineers, Denver, Colorado; Christine S. Dayton, Kaiser-Hill, Project Manager, Rocky Flats, Colorado.

INTRODUCTION

The surface soils over portions of the Rocky Flats Environmental Technology Site (Site) were contaminated by accidental releases of radionuclides including plutonium-239,240 (Pu-239/240) and americium-241 (Am-241) (actinides). The Pu-239/240 and Am-241 are strongly associated with the soil particles and do not dissociate significantly in water. Remediation of the actinide-contaminated soils is planned prior to Site regulatory closure. At that time, the soils must be clean enough so that when eroded and transported into streams and ponds, the surface-water Pu-239/240 and Am-241 concentrations will not exceed surface water-quality standards. Understanding the processes and variables that contribute to and control soil erosion is important to achieving a final remedial design that limits erosion, sediment transport, and associated migration of residual actinide contamination.

The Water Erosion Prediction Project (WEPP) model (USDA, 1995) was used to estimate the runoff and sediment yields from Site hillslopes and to estimate runoff and sediment loading to watershed channels. The WEPP sediment and runoff output were then input to the Sedimentation In Stream Networks (HEC-6T) model (Thomas, 1999) to estimate stream flow and sediment transport. The combined output of the WEPP and HEC-6T models was used to estimate surface water concentrations and identify sources, and sinks for Pu-239/240 and Am-241 in the watersheds (K-H/RMRS, 2000). The models were calibrated using Site monitoring data.

A comprehensive geostatistical analysis of the spatial distribution of actinide contamination in Site surface soils was developed using kriging, a geostatistical method for spatial contouring of soil concentration data (Chromec et al, 2000). Quantities of Pu-239/240 and Am-241 associated with the delivered sediment were estimated using the kriged distributions of Pu-239/240 and Am-241 activity-concentrations in the soil combined with data quantifying the particle-size distribution of the actinides in surface soil water-stable aggregates (RMRS, 1998a).

The kriged Pu-239/240 and Am-241 distributions and the erosion and sediment transport model outputs were linked to create: 1) Soil mobility maps; 2) actinide mobility maps; 3) estimated surface-water total suspended solids and actinide concentrations; and 4) tools to guide remediation and environmental management decisions at this Site and others.

METHODS

Model Development: Data used as inputs to WEPP and HEC-6T models must be representative of the degree of observed geographical variability of the landscape at the Site. The model requires that the parameters for each hillslope be constant laterally (perpendicular to the fall line). Watershed sub-basins and hillslopes boundaries were developed from a Digital Elevation Model (DEM) using ArcView Spatial Analyst™ and ground-truthing. The hillslope boundaries were entered into Arc/Info™ as polygons, and lengths and hillslope areas were calculated for each hillslope. The number and size of overland flow elements (OFEs) within each hillslope were derived from intersecting soil series and vegetation-type boundaries over the Site. The resulting OFE polygons were then overlain on the hillslope coverages in Arc/Info™ (Spitze et al., 2000).

The topographic data from the Site DEMs, in which slopes are constantly varying, were used to produce average WEPP hillslope profiles that were as realistic as possible (Figure 1). The best estimates of the slope values were made by placing multiple transects perpendicular to the elevation contours on each OFE, and sampling each transect arc at regular intervals for instantaneous slope values. These values were then averaged laterally across the OFE, and WEPP slope files were generated.

The predicted spatial distributions of soil erosion and Pu-239/240 and Am-241 movement were derived from Geographic Information System (GIS) interpretations of the erosion modeling results, combined with the kriging analysis of the Pu-239/240 and Am-241 contamination in the surface soil. The data on contaminant and erosion distributions were mapped separately, and the information was joined to create actinide mobility maps. The actinide mobility maps show areas that are both erosion prone and contaminated, and thus where the Site will benefit most from soil remediation and erosion/sedimentation control actions.

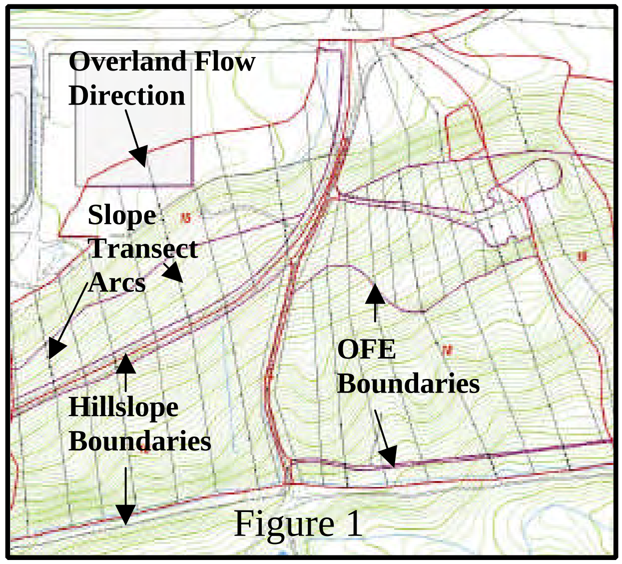


Figure 1

HEC-6T input included field data for channel geometry, bed sediment grain-size distribution, and channel roughness, supplemented by existing Site data, such as 2-foot contour mapping, floodplain mapping, and surface-water discharge and sediment yield data.

Model Integration: The WEPP output was formatted for input to the HEC-6T model, which produces output that predicts the transport and deposition of sediments. Integrating WEPP and HEC-6T was accomplished by the following procedure:

- The WEPP-estimated peak runoff (i.e., peak discharge) and runoff (i.e., total yield) values were used to compute triangular unit hydrographs for each tributary inflow (hillslope). The triangular distributions used for HEC-6T were constructed to match the rainfall intensity distributions such that peak discharge occurred at one-sixth of the runoff duration for the 6-hour events, one-fourth of the runoff duration for the 11.5-hour events, and one-fifth of the runoff duration for the 2-hour event;
- The time step for the runoff portion of each HEC-6T model was set using the shortest tributary runoff duration within a watershed. The time step was adjusted until each tributary in HEC-6T produced a runoff yield that matched the WEPP model output to within $\pm$ 10 percent;
- Sediment loads were calculated for each tributary inflow using a triangular unit hydrograph methodology similar to that described above for runoff;
- The WEPP-estimated total sediment yield and the runoff duration calculated in the unit hydrograph procedure (above) were used to compute the peak sediment load for each tributary inflow. The WEPP-estimated peak runoff rate (in cubic feet per second) and the peak sediment load (in short tons/day [short ton = 2,000 pounds]) were then paired for each design storm, thereby forming the data needed for the HEC-6T sediment discharge curve for each tributary inflow;
- Baseflow in the main channel, upstream from all of the tributary inflows, was set to simulate observed conditions based on monitoring data from Site stream gages;
- Discharges from hillslopes were loaded into the channel segment(s) as inflows. Where two or more hillslopes contributed flow and sediment load to the same point in the main channel, the flows for each hillslope were summed using the triangular unit hydrograph method;
- The WEPP-estimated particle-size distribution (five size classes) and the estimated specific gravity of the inflow sediment were obtained for each hillslope and adjusted to the nine size classes required as input to HEC6-T by fitting the WEPP data to a log-normal distribution determined from data on Site surface soils; and
- Later, the measured particle-size distribution of the actinides in the parent soil was assigned to the WEPP and HEC-6T output data to calculate actinide concentrations in the surface-water.

Methods were developed to use the WEPP and HEC-6T output for estimating transport of Pu-239/240 and Am-241 associated with the suspended sediments. A model was created to calculate actinide transport based on the erosion of hillslope soils and kriged activity-concentration levels. Actinide contributions from channel erosion were not included in the calculated concentrations due to assumptions inherent in the channel erosion component of HEC-6T.

A soil actinide concentration adjustment model was created to estimate levels of soil contamination that can remain in the Site soils and be protective of surface water quality. The adjustment model can be used as a tool to develop the Site's final remedial design.

RESULTS

The following are a sampling of results derived from the modeling analysis (K-H/RMRS, 2000):

1. Uncertainties in the erosion and sediment modeling results and the assumptions have been identified, qualified, and quantified where possible. Comparisons of model estimates to surface-water monitoring data provide examples where erosion and sediment transport are underestimated and other examples where erosion and sediment transport appear to be overestimated by as much as a factor five. Figure 2 illustrates one problem encountered during model validation. The monitoring data are highly skewed towards small storms, total dissolved solids is not routinely collected and has a short period of record.

2. The 100-year annual average erosion rate for the three Site watersheds was estimated to vary from 0.384 metric tons per hectare (T/ha) to 0.221 T/ha (0.099 t/ac), resulting from about 4 to 6 percent of the annual precipitation leaving the Site as runoff. The great majority of the predicted erosion is due to large, infrequent storms and the average values do not convey the very large variation in annual values of runoff and erosion due to variation in precipitation from year to year. The annual erosion estimates for the watershed in Figure 3 vary from a minimum of 0.01 T/ha (0.004 t/ac) to a maximum of 3.54 T/ha (1.58 t/ac) for the 100-year simulation. Soil losses more than double the average can be expected about 16 years out of 100 years or about once every 6 or 7 years. The 100-year average is very similar tothe events with a 10- to 12-year return interval.

3. Areas with high erosion potential and actinide source areas that have the potential to impact surface water quality due to erosion and sediment transport were identified using the erosion and actinide mobility maps.

4. Figure 4 is a graphical presentation of model estimated sediment, Pu-239/240, and Am-241 concentrations in Site streams, identifying watershed areas impacted by soil contamination and stream reaches that act as sediment sinks.

Figure 2

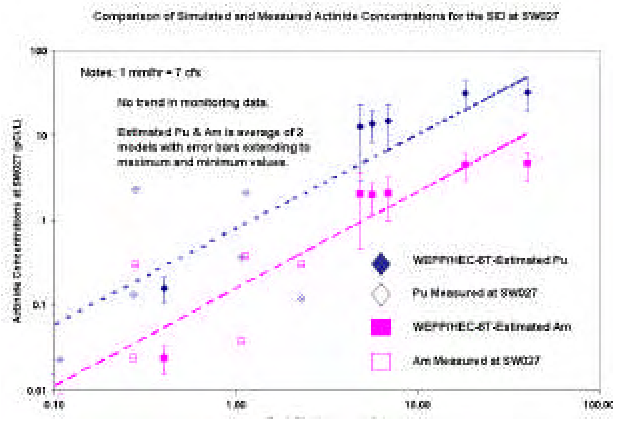


Figure 3

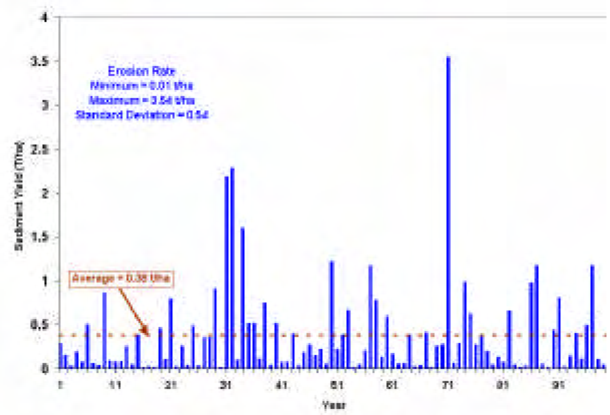
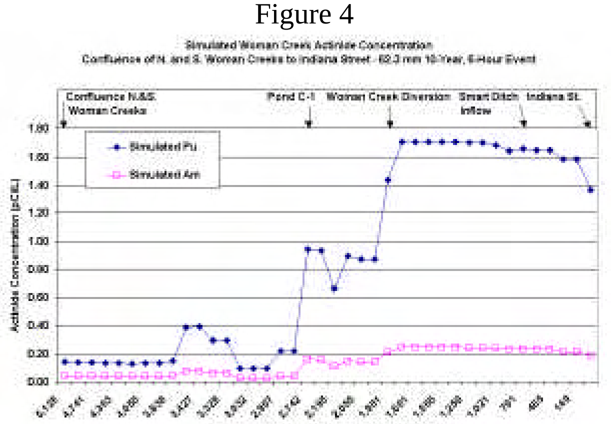
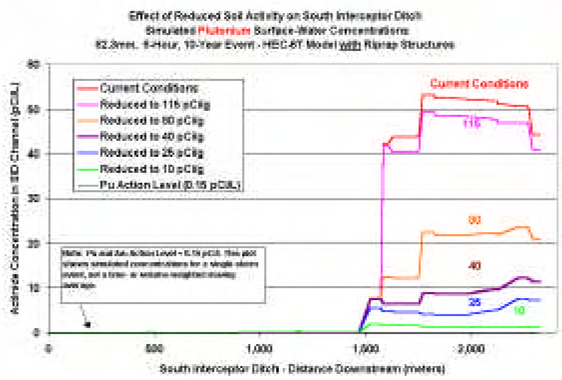


Figure 4



5. The model simulations for the 10- and 100-year events, coupled with the soil actinide concentration adjustment model results indicate that the Site needs to evaluate a combination of remediation, erosion controls, hydrologic controls, and management controls to protect surface water quality in a manner consistent with the goals of the Rocky Flats Cleanup Agreement (RFCA) (DOE, 1996a). The selection of a final remedial design for the Site watersheds will depend on the completion of several steps in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process.

Figure 5



Integration of these models has created tools for making informed decisions regarding remedial actions for actinide-contaminated soils at the Site. The tools will be used to evaluate combinations of soil remediation, erosion controls, hydrologic modifications, land uses, and other management alternatives to assess their impacts on mitigating the movement of Pu-239/240 and Am-241 via the soil erosion and sediment transport pathway. This modeling process can also be applied to soil contamination problems at other sites where contaminants are insoluble and have a strong affinity for sorption or binding to the solid phase (e.g., soil and sediment).

Conclusions derived from this modeling effort should be characterized as preliminary until the modeling work planned for fiscal year 2001 and other related investigations have been completed. Activities planned for fiscal year 2001 include: improved integration of the models; streamlining of data handling and reporting; modeling of future scenarios for soil remediation; hydrologic modifications; extreme natural disasters (floods, fires, etc.); and incorporation into a final land configuration design study for the Site.

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MANAGING EROSION AND SILTATION IN LAKE SIDNEY LANIER, GA

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Bank Stabilization Projects

Riprap is a widely used practice to prevent bank erosion on Lake Sidney Lanier. Lake Lanier, a flood control project managed by the Corps of Engineers just north of Atlanta, Georgia, has initiated an erosion control program in conjunction with its adjacent private landowners.

Landowners interested in stabilizing the shoreline near their private boat docks are permitted to do so with the installation of riprap. Riprap permits require use of filter cloth underlying the rock and the bank, resulting in a slope of 2:1 or less.

To reduce the site impact and future erosion, the Corps of Engineers has authorized contractors to work the material and equipment from barges. Barge use avoids heavy equipment use across Corps property, thus limiting site impact to the immediate shoreline area.

This erosion control program is successful due to the cooperation of the Corps of Engineers and adjacent private landowners. Just in 1999, over 30,000 linear feet of riprap were installed along Lake Lanier's shoreline at a cost to adjacent landowners of more than three million dollars.

Sand Dredging Projects

Sand dredging programs are a necessity in the aging manmade lake projects around the country. Lake Sidney Lanier is a good example of this need with its 50th anniversary just around the corner.

Sand dredging commenced in the Chestatee River, one of the two rivers that flow into Lake Lanier, in 1992. Over time, the sedimentation originating upstream had begun to clog the river channel and make navigation nearly impossible. The Corps of Engineers has permitted a sand dredging contractor to remove silt material from the river channel to improve navigation and preserve the water storage capacity of the lake.

The sand dredging contract is a "win-win" situation for both the Corps of Engineers and the contractor. The Corps of Engineers benefits with the improvement to the river channel and monetary compensation from the contractor. In 1999, the contractor removed 41,455 tons of silt at a price of $12, 750 paid to the Corps. As long as the contractor is able to create a market base for his products, he is able to make a profit on the silt material pumped out of the river. Sand is sold to local concrete companies; river stone and topsoil is sold to area landscape companies and residents.

With the success of the sand dredging operation on the Chestatee, a new contract is currently being awarded to produce similar results in the Chattahoochee River. This new sand dredging contract is hoped to produce an even greater improvement to the navigation of the river channel and water storage capacity of the lake.

Vinyl Sheet Piling

The U.S. Army Corps of Engineers has adapted a coastal solution to erosion control in an inland lake setting: vinyl sheet piling. Lake Sidney Lanier has installed vinyl sheet piling in three of its busy park areas to stabilize the banks and control future erosion.

Vinyl sheet piling is a cost-effective alternative to installing concrete or wooden bulkheads. It consists of lightweight, interlocking panels made of exterior grade vinyl. Its installation is quicker and at a reduced labor cost. The vinyl sheets can be procured quickly, stacked in a warehouse, and then installed with ease. Installation consists of digging a trench with a ditch witch, installing the 4' x 8' vinyl sheets, installing deadman anchors, and back-filling the wall. On-site impacts are reduced from heavy equipment. Manufacturer warranties the vinyl sheets for 50 years.

The Corps of Engineers at Lake Lanier will study the three areas with vinyl sheet pilings for the next five years to conclude if this method of bank stabilization is sufficient to expand to adjacent landowners along the 540 miles of Lake Lanier's shoreline.

GSTARS 2.1 (Generalized Stream Tube model for Alluvial River Simulation) version 2.1

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Abstract: GSTARS 2.1 is a numerical model developed by the US Bureau of Reclamation for simulating alluvial rivers with movable boundaries. It is a quasi-steady state model based on a one-dimensional backwater algorithm that can compute flow transitions (e.g., hydraulic jumps) and mixed regime flows (subcritical, supercritical, or any combination of the two). Sediment is routed using the stream tube concept. Bed changes are computed independently for each stream tube. GSTARS 2.1 sediment transport capabilities cover a wide range of conditions, such as fractional transport, bed sorting and armoring, over 10 sediment transport functions for sizes ranging from clay to gravel, and non-equilibrium sediment transport. Other special capabilities include a simple bank stability criteria and the computation of channel width changes based on the theory of total stream power minimization.

GSTARS 2.1 is distributed with a new graphical user interface designed to improve interaction between the user and the numerical model. The graphical user interface was developed using the Java programming system. GSTARS 2.1 runs on PC-compatible computers running under the Microsoft Windows 9x/NT operating system. Distribution is free and unrestricted via the Web (see www.usbr/gov/srhg and follow the links).

The poster session will highlight features of the GSTARS 2.1 model. Examples of application of the model will be presented, including the results of some verification/validation runs.

WATER QUALITY FROM FLOODWATER RETARDING STRUCTURES

By R. F. Cullum, Agricultural Engineer, USDA-ARS National Sedimentation Laboratory, Oxford, MS; and C. M. Cooper, Ecologist, USDA-ARS National Sedimentation Laboratory, Oxford, MS

Abstract: Water quality assessments were conducted from 1991 through 1996 on tributaries below four floodwater retarding structures built in north central Mississippi, two equipped with low flow augmentation and two without low flow augmentation. This presentation summarizes the stage-discharge relationships, sediment loading, and water chemistry in four tributaries of Otoucalofa Creek below the earthen dams before and after construction. Comparison of the dams with and without low flow augmentation features showed augmentation maintained base flows for longer durations in dry months providing a more stable aquatic habitat. When storm flows before and after reservoir construction were compared, peak flows were reduced as expected at all gauging sites. Floodwater retarding structures raised average stages giving landowners more usable water. Sediment concentrations were reduced by 61% resulting in significantly cleaner water downstream of the reservoirs. While at this time no quantitative way exists to measure if flooding will reoccur or flooding impacts in and around Water Valley, Mississippi, the eight completed floodwater-retarding structures reduce the potential of flooding Water Valley. Water Valley has not flooded with the construction of these earthen structures. Significant use of these created lakes by wildlife and waterfowl was observed. Landowners wasted little time in stocking these lakes with their favorite fish.

INTRODUCTION

Otoucalofa Creek is a fourth order stream originating and flowing (37 km) through three counties (Yalobusha, Lafayette, and Calhoun) in North Central Mississippi (USA) before joining the Yocona River and emptying into Enid Reservoir. The creek drains approximately 29,000 ha (71,000 acres) through channels that were 64% stabilized by snag and debris removal in the mid-1980's and early-1990's. Enid Reservoir receives this drainage into its permanent man-made pool of approximately 2470 ha (6100 acres) and flood control pool of 11,340 ha (28,000 acres). In 1989 the Natural Resources Conservation Service (NCRS) and the Agricultural Research Service (ARS) collaborated on a project to install and evaluate a series of floodwater retarding structures (FWS) on tributaries of Otoucalofa Creek. Plans for this project were first discussed in 1988 with postponements for various reasons pushing scheduled startup and completion dates of the first lakes into 1994. Only eight of the originally planned twenty-six FWS were completed due to fiscal cutbacks. Project goals were to reduce flooding in and around Water Valley (population 4000), a small town in the central Otoucalofa Creek floodplain, and to reduce sediment loading and transport into Enid Reservoir by catchment and controlled release of runoff from the small watershed lakes created behind the FWS. This project was one of many in the larger Demonstration Erosion Control (DEC) Project evaluating new erosion control technology in the Yazoo Basin of North Central Mississippi.

The objective of this paper was to evaluate the effect of floodwater retarding structures and low flow augmentation on water quality. Four gauging sites for stage-discharge relationships and water sampling for sediment and chemical analyses were positioned on undisturbed reaches of the Otoucalofa Creek in close proximity to the NRCS standard earthen design dams. Gauging sites were established three years prior to the 1994 construction of dams to establish background flows and sediment loadings.

Descriptions of Watersheds and Floodwater Retarding Structures: Study sites were located on land owned by Weyerhaeuser Timber Company (managed by Mr. Darryl Maddox), Mr. Charles L. Costner, Mr. Tommy Fay Inman, and Mr. James A. Mosley, and are hereafter referred to as FWS-1, FWS-2, FWS-3, and FWS-4, respectively. Watershed area and floodwater retarding structure design specifications for the individual lakes can be seen in Table 1.

Falaya and Collins series soils predominated the creek floodplains with Dulac, Providence, and Freeland soils on the gentler slopes (2-12%), and Cuthbert, Dulac, and Ruston mixes on the steeper slopes (12-35%). Erosion on slopes surrounding the creek floodplains was moderate to severe according to the SCS Soil Survey of Calhoun County, Mississippi.

Undisturbed watershed timber consisted mostly of a mix of oaks, poplar, sweetgum, and hickory as well as scattered pines and eastern red cedar. Understory vegetation increased in density nearer the creek channels and was a mix of shrubs, vines, and grasses. Land use alterations along parts of the channels included a small stand of 20 year-old planted pines at FWS-1, cattled pasture at FWS-3, and cattled pasture alternated with cropping (corn and millet) at FWS-4. FWS-2 was essentially undisturbed until midway through the project when it was logged (clear-cut on slopes and selectively cut in floodplain). Selected timber was cut from the top of the creek bank at FWS-4 in 1995 with some debris falling into the channel.

Table 1. Floodwater retarding structure design specifications and watershed areas.

Number	Watershed Size ha (acres)	Permanent Pool Size ha (acres)	Flood Pool Size ha (acres)	Maximum Flow Rate Ls (cfs)	Low Flow Rate Lskm (csm)†
FWS-1	451 (1114)	10.6 (26.3)	26.5 (65.5)	1642 (58)	N/A
FWS-2	306 (755)	6.0 (15.2)	17.3 (42.8)	878 (31)	2.19 (0.2)
FWS-3	179 (442)	5.2 (12.9)	11.0 (27.1)	793 (28)	N/A
FWS-4	309 (762)	8.0 (20.4)	18.5 (45.8)	850 (30)	2.19 (0.2)

† Lskm = Liters per sec per square kilometer; csm = cubic ft per sec per square mile

Description and Criteria of Study Sites: The first four floodwater retarding structures scheduled for completion in Otoucalofa Creek watershed were chosen as study sites. All four FWS were of the NRCS standard earthen design dam with two incorporating low flow augmentation features. The low flow augmentation feature consisted of a smaller secondary release pipe built into the dam to “augment” normally low summer flows. Criteria for site selection and placement of monitoring and sampling equipment were: 1) that they be located in an undisturbed reach of creek in close proximity to the dam, 2) that they be in a relatively straight stretch of creek, and 3) that where possible they be installed in a clay bed at the bottom of the channel. Site locations meeting these criteria were found ranging from 365-457 meters (1200-1500 feet) downstream of the dams.

MATERIALS AND SETUP

Reaches were marked and surveyed in the driest part of the summer of 1990. Four transects were surveyed across the selected 15.2-m (50-ft) reach of each tributary with the third downstream cross section of the reach being the approximate location of the site. A float was timed repeatedly (4 repetitions) through the marked reaches on each tributary and the average time taken to determine the flow velocity. This velocity, in combination with the survey data, was used to calculate flow rates for each channel at any given stage.

At each site a section of 46-cm (18-inch) diameter culvert was cut to the appropriated length and installed vertically in clay in the deepest part of the channel to create a stilling well. Water was blocked off or diverted from the culvert base and concrete poured in and around the culvert base to below channel bottom level. This served to both stabilize the culvert base and to give a constant bottom for reference over the course of the project. Slits and clean-out doors were cut in the base of each culvert to allow water entry and sand and/or sediment removal following storms. A catwalk was built from the stream bank and attached to the culvert. Potentiometer equipped Belfort chart-type stage recorder (float and tape) was placed in instrument shelter on top of each stilling well (Cullum, et al. 1992). The potentiometer transmitted stage (float rise) to an Omnidata Model EL824-MS Easylogger (version 3.02) in a separate instrument enclosure where data was recorded on storage packs until retrieval. Easyloggers were programmed to activate adjacent Isco Model 3700 composite water samplers (Grissinger and Murphree, 1991) when a preset stage and amount of runoff were detected. The water samplers were mounted on large polyethylene containers and programmed to take time-weighted (5-minute interval) composite water samples. A 12-volt marine rechargeable battery connected to a diode-equipped solar panel provided power for all instrumentation. A raingage was installed at FWS-3 to monitor watershed precipitation.

Sites were checked following heavy individual storm events or weekly depending on rainfall. Strip charts from stage recorders were changed on each visit to sites as was raingage chart at FWS-3. Data storage packs (dsp’s), Easylogger programs, and power supply voltage were checked at each site. Dsp’s were exchanged when remaining storage capacity was 30% or less and returned to the National Sedimentation Laboratory for transferring into personal computer using Crosstalk (a registered trademark) communication software. Files were converted into spreadsheet files for data analysis.

After the automatic water sampler collected composite runoff samples through the runoff event, the water container was removed from the instrument house, water samples thoroughly mixed, and two 1-liter composite water samples were taken in collapsible plastic containers. On return to the laboratory, one of these samples was immediately refrigerated for chemical analysis and the other sample was used for chlorophyll and sediment analysis. Water samples were collected from the channel weekly, using a bucket and rope, and treated and analyzed similar to the previous runoff samples. Samples later were taken biweekly after sufficient background data was collected.

Hydrographs for each of the four sites were either recreated from the stage and information recorded in the Easylogger or generated from the stripchart of the stage recorder.

RESULTS AND DISCUSSION

The floodwater retarding structures controlled the discharge and rate from the contributing drainage area above the tributaries by reducing peak stage or flowrate and increasing average stage or flowrate. Several stage-time hydrographs before and after FWS construction for rainfall events greater than 25 mm (1in) showed these trends.

The runoff hydrographs were subdivided into three time periods based on the construction phase of the earthen dams- before, during, and after floodwater retarding structure construction. The period during construction was eliminated from these assessments. Rainfall during this period was taken out of the analyses. A maximum of 34 rainfall events measuring one inch or greater produced significant runoff events from gauging sites from 1991 through 1996 which were subdivided into before construction and after construction periods. Water parameters and chemistry of the runoff resulting from these rainfall events were documented in Table 2.

Table 2. Gauging station stage, discharge, total flow, total rainfall, and water chemistry.

Structure	Average Stage (m)	Maximum Stage (m)	Average Discharge (L s^{-1})	Maximum Discharge (L s^{-1})	Total Flow (ML)	Total Solids (mg L^{-1})	Dissolved Solids (mg L^{-1})	Suspended Solids (mg L^{-1})	Total Rainfall (mm)
FWS-without LF†									
Pre Construction	0.18	0.79	140.73	2485.35	47.33	351.50	75.50	276.00	4362
Post Construction	0.32	0.55	210.68	694.32	137.59	219.00	57.50	161.50	4738
% Change	79.7	-30.0	49.7	-72.1	190.7	-37.7	-23.8	-41.5	8.6
FWS-with LF‡									
Pre Construction	0.13	0.71	75.32	2092.03	21.58	682.00	76.00	606.00	4362
Post Construction	0.30	0.45	109.87	510.83	56.96	106.50	41.50	65.00	4738
% Change	132.6	-36.2	45.9	-75.6	163.9	-84.4	-45.4	-89.3	8.6

Structure	Temperature (°C)	Conductivity (mS/cm)	pH	FOP (mg L^{-1})	TP (mg L^{-1})	NH_4 (mg L^{-1})	NO_3 (mg L^{-1})	Chlorphyll (mg L^{-1})	Dissolved Oxygen (mg L^{-1})
FWS-without LF†									
Pre Construction	14.6	37.5	6.0	0.032	0.512	0.252	0.138	13.16	8.7
Post Construction	16.4	54.0	6.5	0.018	0.141	0.182	0.093	15.24	10.0
% Change	12.3	44.0	8.5	-43.8	-72.5	-27.8	-33.0	15.8	15.0
FWS-with LF‡									
Pre Construction	14.2	22.0	6.0	0.032	0.512	0.130	0.185	7.05	8.9
Post Construction	18.4	43.5	6.7	0.018	0.141	0.184	0.197	22.85	9.7
% Change	29.4	97.7	11.3	-45.3	-72.6	41.5	6.8	224.3	9.4

Controlled release of flow after dam closure reduced both maximum stage and maximum discharge. As a result of reducing peak stage and peak discharge, the average stage and discharge are higher for longer time periods (Table 2). Average stage was increased by an average of 105% and maximum stage was reduced by 33%. Average discharge was increased by 48% and peak discharge was decreased by 74%. The average stage of the tributaries before construction resulted in higher variability than that stage from the low flow augmentation dams after construction. Flow from the low-flow pipes would not be measurable during runoff events due to the large quantities flowing through the riser. Normal flow regimes were great enough during low flow so that flow augmentation was not significant. Low flow augmentation would be a positive factor during drought periods when base flow would remain stable for a longer duration.

Total solids were reduced an average of 61% due to the settling of the suspended solids in the catchment of the dam when compared to before dam construction. Suspended solids were reduced by 65% and dissolved solids were reduced by 34.6% when comparing before and after construction periods.

Other water quality changes were also related to "ponding" effects (Table 2). Temperature increased 2 to 4 °C because the greatly enlarged surface area and water residence time allowed warming from solar radiation. The slight increases in conductivity were likely linked to increased evaporation and phytoplankton production. Phytoplankton varied in individual streams before reservoir construction and was dependent upon solar radiation/riparian vegetation and water residence time as impacted mainly by beaver dams. After dam closure, theponded water began to develop a standing water phytoplankton. The increase in primary productivity removed hydrogen ions and increased the pH of water in all four reservoirs as was measured by chlorophyll.

Both filterable ortho-phosphate and total phosphorus were reduced, as expected, by an average of 44 and 72 percent, respectively. Reduction resulted from settling of suspended solids and increased phytoplanton growth as the result of ponding and increased residence time. Ammonium and nitrate concentrations were not significant before or after construction. All water quality parameters were below limits set by the Environmental Protection Agency.

An interesting note was the beaver activities in creating their own dams within this project area. For all the problems they caused during this project, beaver dams and pools were producing similar effects as the FWS lakes were designed to do, except on a smaller scale. Of course timber damage due to feeding and flooding by beavers would be unacceptable in many areas, but there is a potential benefit for their use in acceptable areas or in large isolated public or private lands with problems similar to this study area.

CONCLUSIONS

Benefits of this project were numerous. Low flow augmentation apparently maintained base flow for a longer time in dry summers and the floodwater retarding structures raised average stages giving the landowners more usable water according to personal communication with landowners. Sediment concentrations were reduced by an average of 61% resulting in proportionally cleaner water flowing into Enid Reservoir. While at this time there is no quantitative way to measure flooding impacts in and around Water Valley, or that flooding will not reoccur, it is reasonable to assume that the eight completed FWS will reduce that potential. Although not part of this study, significant use of these FWS-created lakes by wildlife and waterfowl was noticed. Also, the landowners wasted little time in stocking these lakes with their favorite fish. Projects of this type can benefit many people and require careful economic cost/benefits analysis. Maximum benefits from this project would have been achieved had all FWS planned been completed. The reality was that this was a costly project and that fiscal reductions cut both the project scope and staff designing these structures. For anyone considering evaluating a similar project, the project is highly recommended to be relatively close for site servicing or if that is not possible that some sort of telemetry is used to monitor site/sampler activity.

ACKNOWLEDGEMENTS

The authors thank personnel from the Agricultural Research Service and the Natural Resources Conservation Service (NRCS). NRCS provided necessary landowner and site information. In particular, we would like to thank Terry Welch for his valuable assistance in this study.

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TURBIDITY THRESHOLD SAMPLING: METHODS AND INSTRUMENTATION

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Traditional methods for determining the frequency of suspended sediment sample collection often rely on measurements, such as water discharge, that are not well correlated to sediment concentration. Stream power is generally not a good predictor of sediment concentration for rivers that transport the bulk of their load as fines, due to the highly variable routing of sediment to the channel from hillslopes, roads, and landslides. A method, such as turbidity threshold sampling, that employs a parameter well correlated to concentration, can improve sampling efficiency by collecting samples that are distributed over a range of rising and falling concentrations. The resulting set of samples can be used to estimate sediment loads by establishing a relationship between concentration and turbidity for any sampled period and applying it to the continuous turbidity data. All river systems, particularly smaller watersheds that respond very quickly to rainfall, benefit from automated data collection.

A data logger, under direction of the turbidity threshold sampling program, collects stage and turbidity data at 10 or 15-minute intervals, depending on the drainage size, then periodically triggers an automatic pumping sampler to collect a sample when specified conditions have been satisfied. The program uses a set of rules to improve the efficiency of sample collection. The program collects 60 turbidity readings in 30 seconds and then selects the median value. This reduces outliers by integrating sediment pulses and rejecting false values. The program also attempts to distinguish false spikes from true rises in turbidity, and it uses different sets of rising and falling thresholds.

The turbidity probe, mounted inside of a housing, and the sampler intake, are usually attached to the end of an articulated boom. Booms are most suited to sites that have adequate depth of flow. The boom and housing reduce contamination from organics by shedding debris, protecting the sensor from direct impacts by woody material, and when properly designed, they can reduce hydrodynamic noise caused by turbulence and the entrainment of air or re-suspension of sediment close to the sensor. Field personnel can retrieve the bank or bridge-mounted boom to remove debris during high flows. The boom controls the depth of the turbidity probe and sampler intake in the stream to maintain their position above bedload transport and below the water surface.

Sampling Coarse Suspended Sediment in Steep Gradient Sierran Streams

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It is difficult to sample the sand sized granitic particles that move down steep gradient Sierran streams because many samplers cannot lift these large particles. Failing to sample them presents an inaccurate picture of sediment loads and nutrient flux in first order streams.

This poster will compare the suspended load samples captured by double vacuum samplers and peristaltic samplers to depth integrated hand samples. The double vacuum samplers claim intake line speeds of 8-10 ft/sec, twice that of most peristaltic samplers. This trial will determine if the increased line speeds significantly improve the sampling of larger sized particles. These samplers will be run off 12-volt batteries that are charged by solar panels.

This sampling is part of the baseline data for The Kings River Sustainable Forest Ecosystem Watershed Project. This is a paired watershed study that is attempting to measure nutrient flux as a result of small group selection harvesting and under story prescribed burning in Sierran conifer forests. The study design has four groups of four small watersheds each containing a control, partial harvest, under story burn and a combined harvest and burn watershed. Stream discharge, water chemistry, sediment load and soil water chemistry are being measured.

ABSTRACT

PHOTO-OPTICAL SEDIMENTATION TUBE

By

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The Visual Accumulation Tube was designed in the nineteen-fifties to improve methods for determining size distribution of sand samples, particularly of suspended sediment samples composed mainly or partly of sand sizes. The importance of the work was justified by the extensiveness of the current field programs of sediment measurements during that time. The emphasis of such analyzer was placed on simplicity, economy of operation, and accurate determination of the fall velocities of the particles composing the samples. The significance of the Visual Accumulation Tube was the determination of fall velocity or sedimentation size instead of physical size or volume of the individual grains.

The need for a laboratory method of analyzing sediment samples, particularly in the sand range, quickly and with reasonably good accuracy appeared to be amendable to solution by means of some type of sedimentation tube. This approach led to the eventual development of the visual accumulation tube apparatus and method.

The Visual Accumulation Tube has been used by numerous Federal and State governments for several decades and served its purpose very well. Though the Visual Accumulation Tube improved on processing time and method, the critical needs that initially formulated the sedimentation tube almost five decades ago still lingers today. There exist a certain amount of urgency to improve or replace the technically out-dated Visual Accumulation Tube, without jeopardizing quality. Generally the needed improvements are; to eliminate the routine manual computations, remove the human element out of the analysis as much that is practical, to increase analytical processing time, compute and store data into a database, and generate reports.

To accomplish this without deviating from the sedimentation tube principles, this project is focusing on producing an analyzer that combines modern technologies with past fundamentals. With increasing speed of computer processors, frame grabbers, and progressing resolution for electronic imaging chips, its possible to produce instantaneous size data from images of falling sand size particles by converting these images into a two-dimensional array for statistical extraction.

The two-dimensional image then is used by an imaging software that uses a set of operators (intersections, union, inclusions, complement) to transform an image to expand the functionality of the image to produce accurate data by defining discrete particles and enhancing their edges. The transformed image usually has fewer details, implying a loss of information, but its main characteristics are still present. Once an image has been simplified by morphological processing, measurements can be computed to give a quantitative analysis of the image.

Current test results have fortified the concept of replacing the existing Visual Accumulation Tube with an optical instrument using recent advancements in technology that has spawned the development of the Photo-optical Sedimentation Tube prototype (PST).

The PST will precisely measures the size and shape of sand size particles. Constituents will include 'x' and 'y' dimensions, area, shape and volume of individual grains. Future amenities will produce the 'z' axis dimension for a three dimensional profiling.

U.S. GEOLOGICAL SURVEY SEDIMENT AND ANCILLARY DATA ON THE WORLD WIDE WEB

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Abstract: A retrieval from the U.S. Geological Survey National Water Information System World Wide Web (NWISWeb) data base yielded more than 2.6-million values of instantaneous-value sediment and ancillary data for 15,415 sites in all 50 States, Puerto Rico, and other locations. The retrieval includes 12,115 sites with suspended-sediment concentration data, about half of which also include particle-size distribution data; 238 sites with bedload discharge data; and 3,623 sites with bed-material particle-size distribution data. Ancillary variables, including water discharge and water temperature, in addition to a large amount of chemical-quality data, are available for many of the sites. The NWISWeb data base represents the single largest repository of USGS electronic instantaneous-value suspended-sediment, bedload, and bed-material data. The NWISWeb data base is described, along with criteria used to retrieve sediment and ancillary data, and selected characteristics of those data.

INTRODUCTION

According to the *National Water Quality Inventory: 1998 Report to Congress*, siltation (a general term applied to fluvial sediment) is considered the top pollutant in U.S. rivers and streams, affecting aquatic habitat, drinking water treatment processes, and recreational uses of waterbodies (U.S. Environmental Protection Agency, 2000a). The U.S. Environmental Protection Agency (USEPA) provides guidance to states, territories, and authorized tribes that exercise their responsibility under section 303(d) of the Clean Water Act for the development of sediment total maximum daily loads (TMDLs) (U.S. Environmental Protection Agency, 2000b). This report summarizes a January 13, 2000, retrieval of electronically available U.S. Geological Survey (USGS) instantaneous-value sediment and ancillary data in support of the USEPA's efforts to develop technically supportable TMDL's based on rational, science-based assessments.

DESCRIPTION OF NWISWEB DATA BASE

As part of its mandate to disseminate water data to the public, the USGS maintains the National Water Information System (NWIS) -- a distributed network of computers and fileservers for storing and retrieving water data collected at about 1.5 million sites around the country (U.S. Geological Survey, 2000a). Many types of data are stored in the NWIS, including those that describe site information, time-series (flow, stage, precipitation, chemical), peak flow, ground water, and water quality.

The National Water Information System on the World Wide Web, termed the "NWISWeb", provides users of USGS water information with a geographically seamless interface to the large volume of USGS water data maintained on 48 separate NWIS data bases nationwide (U.S. Geological Survey, 2000b). Data are updated from the NWIS sites on a regularly scheduled basis, and real-time hydrologic and ancillary data are transmitted to the NWISWeb several times a day. The NWISWeb provides several output options: Real-time streamflow, water-level and water-quality graphs, data tables and site maps; tabular output in html (HyperText Markup Language) and ASCII (American Standard Code for Information Interchange) tab delimited files; and lists of selected sites as summaries with reselection for details.

Data may be retrieved by geographical area, and by category of data, such as surface water, ground water, or water quality. Further refinement is possible by selecting specific retrieval criteria and by defining the output desired. NWIS data come from all 50 states, selected territories and border sites, from 1896 to present. Of the 1.5 million sites with NWIS data, about 1.2 million are wells; 350,000 are water-quality sites; and 19,000 are streamflow sites, of which more than 5,000 provide data on a real-time basis. NWISWeb contains about 4.3 million water-quality records and 64 million water-quality samples. The NWISWeb help system is useful for new users (U.S. Geological Survey, 2000c).

WATER-QUALITY DATA BASE AVAILABLE THROUGH NWISWEB

The NWISWeb water-quality data base represents the single largest repository of electronic USGS instantaneous-value sediment and ancillary data. Daily-value suspended-sediment data collected by the USGS from 1930 through September 30, 1994, are available to the public on-line (U.S. Geological Survey, 2000d). This and subsequent daily-value USGS suspended-sediment data are entered into the NWISWeb data base as the data become available (Susan Trapanese, U.S. Geological Survey, written commun., 2000).

The results of the January 13, 2000, retrieval from the then-under-construction NWISWeb water-quality data base (U.S. Geological Survey, 2000e), which are summarized in this paper, do not include all instantaneous-value sediment and ancillary data collected by the USGS. Only those data that were stored in USGS District Office NWIS data bases in the spring of 1999 were used to populate the NWISWeb data base that was the source of the January 13, 2000 retrieval (John Briggs, U.S. Geological Survey, written commun., 2000). There is evidence that a considerable amount of USGS suspended-sediment concentration data and some bedload-transport data are not available on the NWISWeb.

Because the data in NWISWeb are updated periodically, subsequent summary statistics generated from the NWISWeb data base may differ from those presented herein. The U.S. Geological Survey (2000f) provides an introduction to the water-quality data base.

EXPLANANTION OF USGS PARAMETER CODES

Values for water-quality parameters (including sediment parameters) from samples or measurements (instantaneous values) are stored under unique record numbers that include the site identification number, date, time, ancillary information that describe the sample and sampling method, and water-quality values for physical properties and chemical and biological constituents. Sample information contained in the records is identified by unique 5-digit parameter codes, such as 80154 for instantaneous suspended-sediment concentration and 00061 for instantaneous water discharge. Each parameter code defines a specific type of data and falls into one of three general classes:

1. Site and sampling-event data.
2. Fixed-value codes, which are used to define a certain part of the process of sample collection, processing, or quality assurance.
3. Chemical, physical, and biological data.

The USGS and USEPA use similar parameter-code definitions, although there are exceptions to the definition convention.

RETRIEVAL PROCESS AND CRITERIA

A two-step retrieval process was used to retrieve sediment and ancillary data from the NWISWeb on January 13, 2000. The initial step was to retrieve water-quality records by searching for records with at least one of the 12 retrieval criteria listed in table 1. Subsequently, by using the list of water-quality record numbers established in the first step, the second step was to retrieve sample information for each record, including as many as 13 site and sampling-event parameter codes, and 156 fixed-value and chemical and physical parameter code values. Site characteristic data retrieved included site name, identification number, state, county, and latitude and longitude location. Types of ancillary data retrieved included the agency that collected the sample, the agency that analyzed the sample, stream velocity, stream discharge, water temperature, sampling method, and the type of sampler used.

The current (2000) version of NWISWeb does not support retrieval by specifying parameter codes; however, there is a parameter grouping search criterion available. A user may select the sediment-parameter grouping and retrieve data that are similar to those that formed the basis for this summary.

RETRIEVAL RESULTS

More than 2.6-million values of instantaneous-value sediment and ancillary data were retrieved for 15,415 sites in all 50 States, Puerto Rico, and other locations, including Canada, Federated States of Micronesia, Guam, and Southern Ryukyu Islands, from the NWISWeb data base on January 13, 2000, by using the retrieval criteria described in table 1. The sediment data were collected by methods described by Edwards and Glysson (1999). Retrieval results for selected types of instantaneous-value sediment data grouped by state or other location are summarized in the appendix. One hundred and forty six sites that were retrieved did not contain a value in the State Code parameter at the time of the retrieval; these sites are grouped under the "To Be Determined" category in the appendix. Instantaneous-value water-quality data and descriptive site information were also available at many of the sites but are not described in this paper.

Table 1. Retrieval criteria for U.S. Geological Survey sediment and ancillary data from the NWISWeb data base, January 13, 2000. Records were retrieved from the water-quality data base when suspended-sediment concentration and water discharge, or any of 11 other parameters were contained in the record.
[mg/L, milligrams per liter; cfs, cubic feet per second; mm, millimeters]

Parameter codes related to suspended sediment:
- 80154 sediment, suspended concentration (mg/L) when paired with
  00061 discharge, instantaneous (cfs);
- 70299 solids, residue at 110 degrees C, suspended total (mg/L); and
- 80180 sediment, total, concentration (mg/L).

Parameter codes related to bedload:
- 04122 discharge, sediment, bedload, average unit, composite samples (tons/day-foot);
- 80225 sediment discharge, bedload (tons/day); and
- 80156 sediment discharge, total, suspended plus bed material (tons/day).

Parameter codes related to bed material:
- 80158 sediment, bed material, fall diameter, distilled water, percent finer than 0.062 mm;
- 80160 sediment, bed material, fall diameter, distilled water, percent finer than 0.250 mm;
- 80163 sediment, bed material, fall diameter, distilled water, percent finer than 2.00 mm;
- 80164 sediment, bed material, sieve diameter, percent finer than 0.062 mm;
- 80168 sediment, bed material, sieve diameter, percent finer than 1.00 mm; and
- 80172 sediment, bed material, sieve diameter, percent finer than 16.0 mm.

Suspended-Sediment Concentrations: At least one set of values of instantaneous-value suspended-sediment concentration (USGS parameter code 80154) and instantaneous-value water discharge (parameter code 00061) was available for 12,115 sites, of which 2,929 had at least 30 such values. A map of sites in the United States and Puerto Rico that have at least 30 paired values of instantaneous-value suspended-sediment concentration and water discharge is shown in figure 1.

Suspended-Sediment Particle-size Distributions: Percentages of suspended sand-size and finer material were available for 6,028 sites, of which 1,342 had at least 30 such values. A map of the sites that have at least 30 values of particle-size distribution of suspended sediment is shown in figure 2. Specifically, the parameters sought were either the percentage of suspended-sediment material finer than a sieve diameter of 0.062 mm (parameter code 70331) or the percentage of suspended-sediment material in distilled water having a fall diameter finer than 0.062 mm (parameter code 70342). Additional particle-size distribution data that describe the percentages of selected clay-, silt-, and sand-size fractions are available for many of these sites.

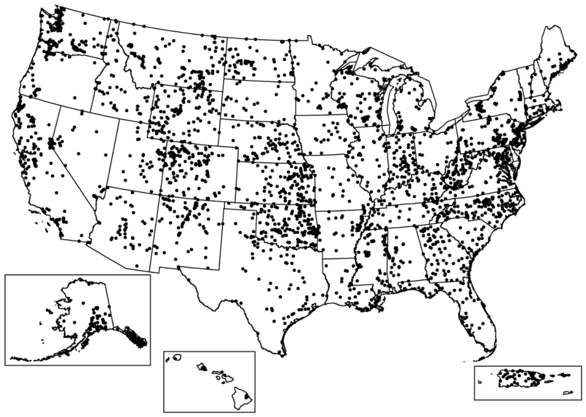

Figure 1. Locations of sites in the United States and Puerto Rico with 30 or more values of paired instantaneous suspended-sediment concentration and water discharge retrieved from the NWISWeb data base, January 13, 2000.

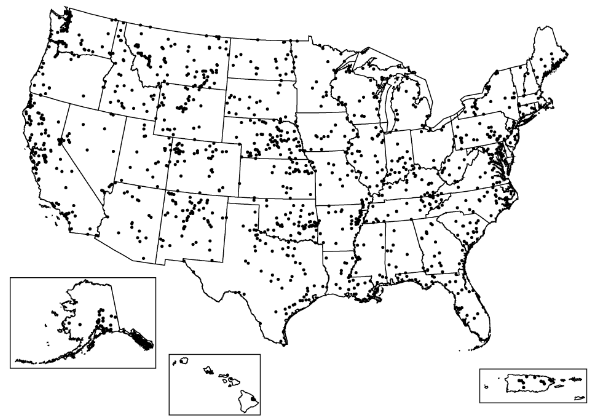

Figure 2. Locations of sites in the United States and Puerto Rico with 30 or more values of particle-size distributions of suspended-sediment retrieved from the NWISWeb data base, January 13, 2000.

Figure 3. Locations of sites in the United States and Puerto Rico with at least 1 value of bedload discharge retrieved from the NWISWeb data base, January 13, 2000.

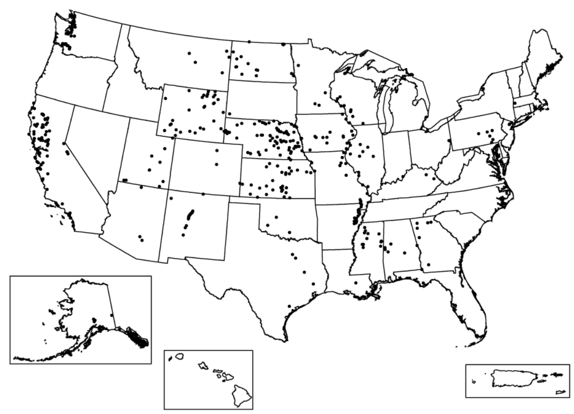

Figure 4. Locations of sites in the United States and Puerto Rico with 10 or more values of particle-size distributions of bed material retrieved from the NWISWeb data base, January 13, 2000.

Bedload Discharge: Bedload-discharge values (parameter code 80225) were available for 238 sites, of which 43 had at least 30 values. A map of the sites that have at least 1 value of bedload discharge is shown in figure 3. Many of the sites also had particle-size distributions associated with the bedload measurement, such as selected sand- and gravel-size fractions.

Particle-size Distribution of Bed Material: Particle-size distribution values of bed material were available at 3,623 sites, of which 474 had at least 10 values. A map of the sites that have at least 10 values of particle-size distribution of bed material is shown in figure 4. The parameters that were retrieved included particle-size distributions based on sieve diameter or fall diameter (USGS parameter codes 80157-80175 inclusive).

Distribution of Drainage Basin Area for Sites with Suspended-Sediment Data: The January 13, 2000, retrieval from the NWISWeb data base found records for 12,115 sites that had at least one pair of values for instantaneous-value suspended-sediment concentration and water discharge. Of these 12,115 sites, drainage area was unavailable for 3,686 sites through the NWISWeb at the time of the retrieval. The distribution of the drainage areas for the remaining 8,429 sites is shown in figure 5. The drainage areas for these sites ranged from 0.002 to 1,140,500 mi ^{2}, and the median drainage area was 72.1 mi ^{2}.

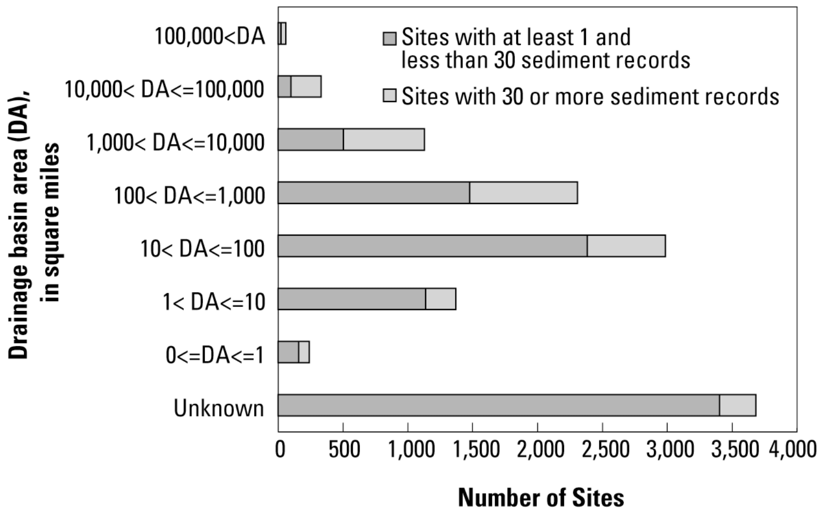

Figure 5. Distribution of drainage areas (DA) for stations with at least one record of paired instantaneous suspended-sediment concentration and water discharge retrieved from the NWISWeb data base, January 13, 2000.

SUMMARY

A retrieval from the U.S. Geological Survey National Water Information System World Wide Web (NWISWeb) data base yielded more than 2.6-million values of instantaneous-value sediment and ancillary data for 15,415 sites in all 50 States, Puerto Rico, and other locations. The NWISWeb data base provides a mechanism to retrieve on-line USGS instantaneous data and is a tool that is easily accessible and straightforward to use. The data base represents the single largest repository of USGS electronic instantaneous-value suspended sediment, bedload, and bed material data.

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APPENDIX. Retrieval results from the NWISWeb data base for selected types of instantaneous fluvial-sediment and water-discharge data grouped by U.S. State, Puerto Rico, and other selected locations, January 13, 2000.

State name	Number of sites with sediment and ancillary data retrieved in State	Sites with suspended-sediment concentration (80154) data and associated water-discharge (00061) data		Sites with particle-size distribution of suspended-sediment data, percent finer than sieve diameter 0.062 mm (70331 or 70342)		Sites with bedload-discharge data (80225)		Sites with particle-size distribution of bed-material data (one or more parameter codes 80157 through 80175)	
		Number of sites with at least 1 sample	Number of sites with at least 30 samples	Number of sites with at least 1 sample	Number of sites with at least 30 samples	Number of sites with at least 1 sample	Number of sites with at least 30 samples	Number of sites with at least 1 sample	Number of sites with at least 10 samples
Alaska	422	412	68	216	30	19	4	40	7
Alabama	266	259	40	32	10	0	0	14	8
Arkansas	159	151	37	123	32	0	0	36	17
Arizona	179	124	46	60	23	1	1	69	3
California	639	450	185	407	139	129	21	339	84
Colorado	591	575	136	266	48	16	2	70	2
Connecticut	222	85	16	19	7	0	0	156	0
Dist. of Columbia	1	1	1	0	0	0	0	0	0
Delaware	2	2	1	2	1	0	0	0	0
Florida	596	82	28	39	21	0	0	134	1
Georgia	244	202	72	146	22	0	0	100	8
Hawaii	60	59	21	26	9	0	0	8	0
Iowa	187	123	28	59	20	0	0	99	16
Idaho	419	398	47	180	30	12	9	30	0
Illinois	309	268	33	250	26	0	0	69	12
Indiana	349	257	59	187	18	6	0	49	0
Kansas	410	366	118	208	29	0	0	157	38
Kentucky	401	389	53	158	26	0	0	30	3
Louisiana	648	68	28	70	28	0	0	33	1
Massachusetts	102	44	12	25	7	0	0	60	1
Maryland	137	104	18	31	6	0	0	39	0
Maine	27	25	10	13	9	0	0	3	0
Michigan	225	221	56	75	24	0	0	35	0
Minnesota	438	239	35	186	18	0	0	92	5
Missouri	135	129	24	101	19	0	0	34	13
Mississippi	189	170	66	43	14	0	0	33	13
Montana	379	377	114	319	85	0	0	28	5
North Carolina	333	309	127	141	19	0	0	64	0
North Dakota	218	146	57	112	21	5	0	146	16
Nebraska	221	156	73	146	74	0	0	191	73
New Hampshire	31	20	3	16	3	0	0	5	0
New Jersey	289	269	67	46	13	0	0	97	3
New Mexico	359	326	84	279	61	0	0	137	43
Nevada	156	119	46	99	21	6	2	20	0
New York	313	259	65	123	32	0	0	151	0
Ohio	428	422	22	73	4	0	0	52	1
Oklahoma	247	210	145	120	51	0	0	14	3
Oregon	425	351	48	116	21	0	0	100	0
Pennsylvania	956	808	114	73	35	0	0	185	6
Puerto Rico	159	129	43	41	11	0	0	11	0
Rhode Island	10	6	1	5	1	0	0	1	0
South Carolina	58	42	16	42	16	0	0	3	0
South Dakota	130	120	21	77	18	4	0	26	1
Tennessee	273	240	44	203	27	0	0	48	0
Texas	249	241	74	182	62	0	0	42	5
Utah	164	152	42	91	20	0	0	49	10
Virginia	224	219	31	65	16	0	0	24	0
Vermont	23	20	3	13	2	0	0	5	0
Washington	719	453	130	170	34	0	0	152	18
Wisconsin	510	475	111	270	28	0	0	123	12
West Virginia	642	637	94	43	11	0	0	25	0
Wyoming	370	337	112	219	36	38	4	153	30
Other Locations									
Canada	11	4	3	4	3	0	0	7	0
Federated States of Micronesia	4	4	0	0	0	0	0	0	0
Guam	8	2	1	1	1	0	0	6	0
Ryukyu Islands, Southern	3	0	0	0	0	0	0	3	0
To Be Determined	146	59	0	17	0	2	0	26	16
Total	15,415	12,115	2,929	6,028	1,342	238	43	3,623	474

A NATIONAL QUALITY-ASSURANCE PROGRAM FOR SEDIMENT LABORATORIES OPERATED OR USED BY THE U.S. GEOLOGICAL SURVEY

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INTRODUCTION

A national program to quality assure fluvial suspended-sediment analytical data produced by laboratories operated or used by the U.S. Geological Survey (USGS) has evolved since 1996. The objective of the National Sediment Laboratory Quality Assurance (NSLQA) Program is to ensure that suspended-sediment data produced or used by the USGS are documented and of known quality, and are sufficient to provide long-term data comparability and consistency on a national basis. The principal focus of the program is to assure the quality of data produced by sediment laboratories operated or used by the USGS. Sediment laboratories operated by other U.S. Federal agencies and Canada also have participated in the NSLQA Program. Sediment laboratories from other countries may participate in one or more components of the NSLQA Program on a trial basis.

The NSLQA Program combines and augments several pre-existing quality-assurance activities to provide quantitative information on sediment-data quality to sediment-laboratory customers. The Program also focuses on quantitative analyses of water-sediment mixtures to derive sediment concentrations, percentages of sand-size and finer material, and more detailed particle-size distributions that are completed by the visual accumulation tube and sieve/pipette, Sedigraph[1], and bottom-withdrawal methods; it also includes on-site qualitative reviews of sediment-laboratory operations, procedures, and equipment.

COMPONENTS OF THE NATIONAL SEDIMENT LABORATORY QUALITY-ASSURANCE PROGRAM

The NSLQA Program consists of the following components:

- Certification training in laboratory operational procedures,
- On-site laboratory evaluations,
- A single-blind reference sediment-sample project,
- A double-blind reference sediment-sample project,
- Data analysis and reporting for each laboratory and on a national basis,
- Follow-up evaluations, and
- Documentation of laboratory quality-assurance plans and quality-control procedures.

Certification Training in Laboratory Operational Procedures Chiefs of sediment laboratories operated or used by the USGS are required to complete USGS certification requirements. This

[1] The brand names in this report are for identification purposes only and do not constitute endorsement by the U.S. Geological Survey

normally includes a 1-week training period under a certified sediment-laboratory chief, and attendance at periodic meetings of sediment-laboratory chiefs. Those certified as sediment-laboratory chiefs are authorized to provide certification training to others.

On-Site Laboratory Evaluations: Each participating sediment laboratory is normally evaluated on-site at 3-year intervals. A sediment-laboratory reviewer certified by the USGS leads the on-site evaluation of the USGS and contract sediment laboratories. A standardized approach is used that objectively documents laboratory facilities, procedures, and performance. A verbal summary is followed by a written evaluation within about a month of the completion of the review.

Single-Blind Reference Sediment-Sample Project: The Sediment Laboratory Quality-Assurance Project (Gordon and others, 2000; Gordon and Newland, 2000; U.S. Geological Survey, 1996, 1998, 2000a), which was initiated in 1996, is a key part of the NSLQA Program. The Sediment Laboratory Quality-Assurance Project distributes single-blind reference sediment samples to participating laboratories, and compiles and statistically analyzes their results to quantify the bias and variance of suspended-sediment data produced by the laboratories. Two sets of nine standard-reference sediment samples are distributed annually to participating laboratories. The samples are identified as quality-assurance samples, but neither their sediment-concentration nor particle-size distribution values are divulged until analytical results and methods are reported. In turn, participating laboratories receive a compilation of results specific to their laboratory upon completion of the analysis.

The results from these tests are used as one tool to assess the performance of individual sediment laboratories by using the aggregate data summary and other information as references. The test results are also used to populate a national, sediment-laboratory quality-assurance data base.

Double-Blind Reference Sediment-Sample Project: The double-blind reference sediment project provides the capability for those submitting environmental water-sediment samples to participating laboratories to also submit quality-control samples that are disguised as environmental samples (Gordon and others, 2000; Gordon and Newland, 2000). Like the single-blind reference sediment-sample project, the double-blind project is designed to measure the bias and variance of suspended-sediment data produced by participating sediment laboratories. Because the quality-control samples are normally shipped among environmental samples from field offices, the double-blind program includes the added variable of shipping procedures to provide information on bias and/or variance attributable to routine shipping, processing, and handling steps.

The results from these tests are used as another tool to assess the performance of individual sediment laboratories. They are also used to populate the national, sediment-laboratory quality-assurance data base.

Data Analysis and Reporting for Each Laboratory and on a National Basis: Analytical results from all sediment quality-control samples are compiled and statistically summarized both on a laboratory-by-laboratory basis and on a national basis. Laboratories receive custom summaries of their results shortly after the completion of a laboratory inter-comparison study. Reports summarizing the results from multiple studies are periodically published. Gordon and others (2000) provide the first such analysis for the single-blind reference sediment-sample project from 1996-98. The derived national data set is used to develop relative criteria with which to evaluate the performance of each participating sediment laboratory. These criteria will be evaluated and updated as the data base grows.

Follow-Up Evaluations: Follow-up evaluations may be required for laboratories that provide data that plot outside statistically determined data-quality boundaries, and (or) for which substantial deficiencies are detected during on-site reviews. The follow-up evaluations may entail processing additional quality-control samples, an additional on-site evaluation, or both. They may focus on general laboratory equipment and (or) methods, or on a single analytical procedure. The intent of follow-up evaluations is to eliminate the source of the identified problems, increase the competence of the laboratory, and improve the quality of the data it produces.

A laboratory that consistently fails to provide adequate results for one or more analytical procedures within a year of the follow-up evaluation may be barred from providing data derived from the procedure(s) in question for storage on the USGS National Water Information System (U.S. Geological Survey, 2000b) or use by the USGS until adequate proficiency by the subject laboratory is demonstrated. Such decisions are made on a case-by-case basis.

Documentation of Laboratory Quality-Assurance Plans and Quality-Control Procedures The NSLQA Program requires participating laboratories to maintain up-to-date quality-assurance plans that include documentation of all quality-control procedures. Quality-control information, such as charts, analytical results of laboratory quality-control samples, calibration records, and analyst bench logs need to be compiled and available for review for at least the previous 3 years. Laboratory quality-control data are required to be fully documented, readily available, and technically defensible. All data from the single- and double-blind quality-assurance projects must be made available for storage on a national, sediment-laboratory quality-assurance data base.

SIGNIFICANT FINDINGS OF THE NATIONAL SEDIMENT LABORATORY QUALITY-ASSURANCE PROGRAM

The NSLQA Program has made significant findings related to the quality of sediment concentration data produced by USGS laboratories and two cooperating laboratories. These findings, which are based on results for five studies completed between 1996-98 as part of the Sediment Laboratory Quality-Assurance Project (Gordon and others, 2000; Gordon and Newland, 2000), are summarized as follows:

1. **Suspended-Sediment Concentration Data Tend to be Negatively Biased**: The median percent bias ranged from –4.9 to –2.4 percent for concentrations ranging from 50 to 100 mg/L; -5.5 to –1.6 percent for concentrations that ranged from 101 to 300 mg/L; and –1.3 to –0.60 percent for concentrations that ranged from 2,200 to 3,200 mg/L. George and Schroder (1996) determined that about 1.3 percent of the known mass in the sample vial is lost in the sample-transfer procedures that start with the removal of the sample from the vial and end with the material collected on the filter. An additional 1 percent of the mass of the test-sample material passes through the Whatman No. 934-AH filter and is lost unless the filtrate is analyzed by using an evaporation dish. Adherence of fine sediment to sand-size material further contributes to the negative bias of fine sediment (Gordon and others, in press).

2. **Suspended Sand-Size Material Data Tend to be Positively Biased**: Quality-control samples were spiked with sand percentages that ranged from 9 to 28 percent of the mass of fine material. The median percent bias for sand-size material mass ranged from 1.8 to 23 percent for concentrations that ranged from 50 to100 mg/L; 1.5 to 16 percent for concentrations that ranged from 101 to 300 mg/L; and 0.4 to 18 percent for concentrations that ranged from 2,200 to 3,200 mg/L. The positive sand-size material bias probably results

from aggregation of fine sediment to form sand-size materials that catch on a 0.062-mm sieve, and from adherence of fine sediment to sand-size material that collects on the sieve (Gordon and others, in press).

3. **Total suspended Solids Data Tend to be More Variable and Have a Larger Negative Bias than Suspended-Sediment Concentration Data**: Gray and others (2000) and Glysson and others (2000) attribute the relatively large variability and large negative bias associated with total suspended solids analytical results to sub-sampling procedures used to provide aliquots for subsequent filtration, drying, and weighing. The total suspended solids analytical method, which originated for quantifying solid-phase material in wastewater samples, is fundamentally unreliable when used for analyses of environmental samples (Gray and others, 2000).

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STATUS AND TRENDS OF NATIONAL EROSION RATES ON NON-FEDERAL LANDS, 1982-1997

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Abstract: The National Resources Inventory (NRI) is a statistically based survey conducted every five years that has been designed and implemented using scientific principles to assess conditions and trends of soil, water, and related resources on non-Federal lands in the United States--about 75% of the total land area. The USDA Natural Resources Conservation Service conducts the NRI and captures data on soil erosion, land use and cover, wetlands, conservation practices, and other related natural resource concerns from 800,000 statistically located sample sites. NRI data are valuable in examining issues at National, State, multi-county, and eight-digit watershed levels. Data from the latest survey indicate sheet and rill, and wind erosion on cropland have declined by 35 percent--from 3.1 billion tons per year in 1982 to nearly 2.0 billion tons in 1997. This reduction is related to increased use of conservation or Best Management Practices, 1985 and 1990 Farm Bill Programs, and changes in land use. Even with these significant reductions in erosion rates, over 110 million acres, or 30 percent, of the Nation's cropland are still eroding at excessive erosion rates greater than soil tolerance levels. More than 60 million acres of this excessivly eroding land are on fragile highly erodible cropland. This excessive erosion, which amounts to nearly 1.3 billion tons per year leads to concerns about sediments, nutrients, pesticides, and other pollutants impacting water quality, especially in the West and Midwest portions of the country.

INTRODUCTION

The National Resources Inventory (NRI) is a compilation of natural resource information on non-Federal land in the United States--about 75 percent of the total land area. The NRI is conducted every five years by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) in cooperation with the Iowa State University Statistical Laboratory. This inventory captures data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes at more than 800,000 scientifically selected sample sites. The NRI covers all 50 States, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations.

The NRI provides a record of trends in the Nation's resources over time and documents conservation accomplishments as well. At each sample point, information is available for 1982, 1987, 1992, and 1997, so that trends and changes in land use and resource characteristics over 15 years can be examined and analyzed. Because the NRI is based on recognized statistical sampling methods and is scientifically designed and executed, NRI data are valuable in examining issues at National, State, and multi-county levels.

THE SIGNIFICANCE OF SOIL EROSION

Soil erosion is the detachment and initial movement of soil particles due to the kinetic energy associated with water from precipitation, the flow of water over the land surface, or the force of wind blowing over the land surface. The impact of falling raindrops breaks up the soil and detaches individual particles. As the very top layers of soil become saturated, a film of water accumulates on the surface. This film captures the soil particles dislodged by raindrops and, as it moves down slope, detaches additional soil particles as well. This "sheet erosion", which results in the removal of a thin, fairly uniform layer of soil over the entire land surface, removes a high proportion of the lighter organic particles that are critical to soil fertility and health. With increasing flow, the water is concentrated in small channels called rills. "Rill erosion" can remove considerable amounts of soil, as water becomes increasingly erosive when confined to these small channels (Clark, *et al.*, 1985). The current NRI provides estimates of the rate and total amount of sheet and rill erosion on the nation's non-Federal crop and pasture land. The NRI also estimates the rate and amount of wind erosion occurring on cropland.

Soil erosion contributes to the influx of sediments, nutrients, pesticides, and other pollutants into the Nation's water supply and the atmosphere. Sedimentation caused by erosion damages aquatic ecosystems, water reservoirs, drainage and irrigation ditches/canals, navigational channels, and recreational areas. Nutrients, such as fertilizers and animal waste, pesticides, and other pollutants, including bacteria and viruses, are transported along with the sediment and negatively impact water and air quality.

Agriculture is the leading source of water pollution in the United States, with sediment being the major source of water quality impairment (USEPA, 1998). However, through the adoption of conservation tillage practices and implementation of measures outlined in the 1985 and 1990 Farm Bill programs, the agricultural sector has made significant advances in reducing soil erosion.

1997 NRI RESULTS

Preliminary results from the 1997 NRI (released in December 1999, final results currently being prepared) showed that total soil erosion on cropland is substantially lower than in 1982. The 1997 NRI data indicate that total soil erosion in the United States stands at nearly 2.0 billion tons per year. This is a decline of 35 percent from 1982, when total soil erosion on cropland was approximately 3.1 billion tons per year. The successful implementation of the 1985 and 1990 Farm Bill programs has contributed to this decline in soil erosion while concomitantly enhancing landowner stewardship. Additionally, increased use of conservation practices, such as conservation tillage and other Best Management Practices, has influenced the decrease in erosion rates. Finally, changes in land use, specifically, a decline in cultivated cropland acres, has reduced national total erosion levels. The Conservation Reserve Program provisions of the 1985 and 1990 Farm Bills, or Food Security Acts, have set aside up to 34 million acres of highly erodible cropland that are presently planted to permanent grass or trees.

The 1997 NRI shows that the average soil erosion rates on total cropland have declined over the last 15 years as well. In 1982, the soil erosion rate was approximately 8.0 tons per acre per year. In 1997, the soil erosion rate had dropped to nearly 5.0 tons per acre. These rates are striking when compared to selected regional erosion rates early in the 20th century. Prior to 1930, soil commonly eroded at rates in excess of 30 to 40 tons per acre per year. After the Dust Bowl catastrophe in the 1930's, farmers began implementing conservation practices such as contouring and terracing, and erosion rates due to water fell to approximately 12 tons per acre per year. With the adoption of conservation tillage and residue management, the average erosion loss due to water from each acre in 1997 was less than 3 tons per year. As an example, a study by Argabright, et al. (1996) estimated the average cropland erosion rate for a portion of the Northern Mississippi Valley in 1930 was approximately 15 tons per acre per year. The annual rate had been reduced to 7.8 tons in 1982, and was later reduced to 6.3 tons by 1992.

Even with the widespread adoption of soil conservation measures and the enactment of soil and water conservation programs, excessive erosion continues to be a serious problem in many parts of the country. According to 1997 NRI results, 30 percent of the Nation's cropland--over 110 million acres--is excessively eroding, resulting in a total excess rate of 1.3 billion tons per year. Of this total acreage, more than 60 million acres were fragile, highly erodible cropland. (Highly erodible soils are areas where the potential erodibility is 8 times greater than the soil loss tolerance rate.) The remaining 50 million acres were non-highly erodible cropland with erosion that exceeded the tolerable soil loss rate. (The soil loss tolerance rate is the maximum rate of annual soil loss that will permit crop productivity to be sustained economically and indefinitely on a given soil.) Excessive erosion spawns concerns regarding the impact of sediments, nutrients, and pesticides on water quality. In addition, excessive wind erosion in the West, Midwest, Northern Plains, and Southern Plains can contribute to compromised air quality. Where excessive erosion is prevalent, the implementation of conservation practices provides the opportunity to reduce sedimentation, improve soil quality, sequester carbon, and reduce fine particulate matter and greenhouse gases in the atmosphere.

It is estimated that total soil loss from annual sheet and rill, and wind erosion on all non-Federal land uses--excluding urban--has declined from approximately 5.1 billion tons in 1982 to less than 4 billion tons in 1997. Data from previous NRIs indicate that erosion rates on pastureland and rangeland, for the most part, have remained level (USDA, 1994). For pastureland, sheet and rill erosion rates were 1.1 tons per acre per year in 1982, 1.0 tons per acre per year in 1987 and 1992, and 0.9 tons per acre per year in 1997. Wind erosion on pastureland was 0.1 tons per acre per year for 1982 through 1997. Water erosion on rangeland was 1.2 tons per acre per year from 1982 through 1992. Wind erosion on rangeland declined from 4.7 tons per acre per year in 1992 to 4.4 tons per acre per year in 1987 and 1992. (Data were not collected on rangeland in 1997.)

Gully, streambank, roadbank, channel erosion and other related types of erosion are not included in these total erosion estimates, however data from a special 1978 NRI indicates total erosion from these sources was slightly less than 1.1 billion tons per year on non-Federal land. Approximately 50 percent of the total was from stream and streambank erosion, 27 percent was from gully erosion, 17 percent was from roadbank erosion, and 7 percent was from miscellaneous erosion sources/forms. Present erosion amounts are not believed to be much different.

One disturbing finding from NRI related data is an apparent leveling-off in total erosion on cropland. Special erosion studies on cropland that targeted specific changes in resource trends indicate that total soil erosion has been nearly steady since 1995. Despite the gains realized in reducing soil erosion since 1982, agricultural producers continue to face the challenge of controlling erosion on cropland. This plateau in soil erosion reduction raises questions regarding the efficacy of conservation practices and the diligence with which these practices are applied. Erosion is an ongoing natural process; consequently, the soil erosion problem will not be resolved with any finality. Soil erosion will persist, although its impact can be further reduced through the continued, expanded, and intensified application of conservation practices.

SEDIMENTATION

Soil erosion is often viewed primarily in terms of its detrimental effects on agricultural production and as a matter of land preservation or stewardship. The problems of erosion are not confined to the upland areas, but are readily manifested in numerous off-site locations, often far removed from the actual spot where the erosion occurred. Of the nearly 4 billion tons of soil loss from non-channel type erosion occurring on non-Federal land, most of the eroded material is deposited as sediment near the location where movement begins. It settles at the base of slopes, in furrows and ditches, along field borders, or is trapped by conservation practices such as terraces, filter strips, and sediment basins. NRCS estimates (unpublished data) that only 7 to 50 percent of sediment derived from sheet and rill erosion on the landscapes is delivered to small streams. Steep fields or watersheds with finer-textured soils have the higher sediment delivery rates while flatter, and sandier areas have the lower rates. The average delivery rate is estimated to be slightly more than 25 percent (NRCS unpublished data). Approximately 5 percent of sediment entering a small stream is delivered to the outlet of the associated river-basin. The remaining portion is deposited on floodplains, on channel bars, in wetlands, and in lakes and reservoirs. Less than 5 percent of total eroded materials reach the ocean. Of the estimated 1.1 billion tons of soil moved by gully, streambank, and other miscellaneous erosion types, NRCS estimates that about two-thirds of that sediment is delivered to small streams.

CONCLUSIONS

Preliminary results from the 1997 NRI indicate that total soil erosion on cropland has decreased 35 percent since 1982. Despite this achievement, excessive soil erosion persists on over 110 million acres, or 30 percent, of the Nation's cropland. Additionally, special cropland erosion studies related to the NRI indicate erosion rates on cropland have leveled off since 1995. Further reductions in the soil erosion rate may be attained through more intensive application of conservation practices and the introduction of new agricultural technology.

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CORE 4 CONSERVATION

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Abstract

CORE 4 CONSERVATION is a marketing strategy designed to promote voluntary conservation by a partnership effort throughout agriculture. It is not a program; it is an education process to keep farmers and ranchers informed about cost effective ways to reduce potential pollution from non-point sources.

Producers serious about controlling non-point source pollution are supporting CORE4 conservation as a common sense approach to natural resource conservation. The idea is to promote voluntary conservation on the nations farms and ranches. This approach appears to be a win-win situation for agriculture and the general public. CORE4 conservation is easily understood because the focus is on just a few highly specialized conservation practices that keep potential pollutants from leaving the application site. Farmers, ranchers, various agency personnel, and the general public are familiar with most of the practices if they read agriculture literature. CORE 4 conservation is a systematic approach that includes:

Conservation Tillage - leaving crop residue on the soil surface to reduce runoff and erosion, conserve moisture, help keep nutrients and pesticides on the site, and improve profitability.

Nutrient Management - fully managing and accounting for all nutrient inputs help ensure nutrients are available to meet crop and soil needs while reducing nutrient loss from deep percolation and/or runoff. It also helps prevent excessive nutrient buildup in the soil.

Pest Management - utilizes integrated pest management (IPM) concepts that keep pests below harmful levels while reducing applications of agriculture chemicals that may harm the nations water resources.

Buffers - provide an additional barrier of vegetation specifically designed for filtering, trapping or utilizing potential pollutants. The potential pollutants may be taken up and utilized by the plants, or the plants may simply hold the pollutants in place until they can be decomposed the natural way by soil organisms. Buffers include the following NRCS practices:

- Filter strips
- Riparian Forrest Buffers
- Windbreaks
- Field Borders
- Contour Buffer Strips
- Cross Wind Trap Strips
- Grassed Waterways
- Herbaceous Wind Barriers
- Alley Cropping
- Vegetative Barriers

A GIS-BASED DECISION SUPPORT TOOL FOR SITING ANIMAL FEEDING OPERATIONS

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Abstract

In 1999, the Earth Sciences and Resources Institute at the University of South Carolina (ESRI-USC) and the U.S. Department of Agriculture's Natural Resources Conservation Service in South Carolina (NRCS-SC) began collaboration to produce a Geographic Information Systems (GIS)-based Decision Support System (DSS) for siting Animal Feeding Operations (AFOs). The primary function of the decision support tool is the optimum siting of AFOs and the selection of a range of environmentally ranked fields most suitable for land application of associated animal wastes. The siting of AFOs and ranking of farm fields for waste application goes beyond current regulatory requirements and allows one to consider all available environmental and economic data. The DSS, launched from ArcView®, consists of two components:

1. The Spatial Simulation Model in ArcView®
2. The Underlying Access® Database

This Spatial Simulation Module uses map algebra to generate scoring grids based on underlying spatial grid data layers that include environmental data related to feature proximity, water quality, soil properties and regulatory setbacks. The philosophy, mechanics, advantages and constraints of creating Soil Erosion Index grid data in 50 m x 50 m (164 ft x 164 ft) grids is briefly discussed in this document.

The structure of the model is such that any type of spatial data can be evaluated provided it is in an appropriate ArcView® grid format and resides in the correct directory. This creates a powerful tool that allows issues other than water quality (the original purpose of this DSS) to be considered.

INTRODUCTION

Animal feeding operations (AFOs) are perceived as a threat to drinking water supplies in the United States. Potential pollutants from AFOs include nutrients, pathogens, organic matter, and heavy metals. Since North Carolina has been plagued with problems associated with AFOs and associated waste, it has imposed a moratorium on the construction of new AFOs. This moratorium has resulted in a large increase in demand for contract growers (hence AFOs) in South Carolina, especially the counties bordering North Carolina. The increased demand for new AFO development creates a dilemma for the regions in equitably meeting the needs of production agriculture, the environment and society.

Since 1998, the Earth Sciences and Resources Institute at the University of South Carolina (ESRI-USC) has been working with the USDA through the Natural Resources Conservation Service in South Carolina (NRCS-SC) to integrate water quality and animal waste management programs for the USDA field service centers. At present, a working Decision Support System (DSS) based in ArcView® has been developed for Marion and Marlboro counties in South Carolina. The DSS provides the user (conservation officers, technical support staff or extension officers) with a beyond-compliance way of siting AFOs and associated manure application sites while accounting for environmental factors and economic constraints borne by the grower.

DESRIPTION OF THE DECISION SUPPORT SYSTEM

Decision Support System Components

The Decision Support System, launched from ArcView, consists of two components:

- The Spatial Simulation Model in ArcView®
- The Underlying Access Database®

The underlying database serves as a reference and data storage module, connecting temporal data in an Access® database to the spatial data in ArcView®. The heart of the DSS, however, lies in the Spatial Simulation Model, which is briefly discussed below.

The Spatial Simulation Module

This module utilizes functionality of the ArcView® Spatial Analyst® Extension and generates scoring grids based on underlying spatial grid data layers, each grid cell size being 50 m x 50 m (164 ft x 164 ft). Grid data layers include feature proximity grids (e.g., distance to floodplains, potable wells), water quality grids (e.g. fecal coliform, dissolved oxygen, copper, zinc, nutrients associated with a hydrologic unit area), soil-related grids (leachability index and soil erodibility index) and regulatory setback grids (created on the fly by user input).

The scoring grid is created by utilizing map algebra. The program multiplies each grid layer (which is normalized between 0 and 1, 0 being worst score and 1 being best score) by user-defined weighting. In addition, regulatory setback grids are added regardless of weight and denote 'no-go' areas. Given the weights of the respective grids chosen and weighted by the user, and setback grid information, the model then sums each cell into a composite output grid. The scoring grid clearly shows the acceptable sites for building AFOs or choosing waste utilization areas with values ranging from 0 to 100 (0 suggesting the least suitable sites, 100 suggesting the most suitable sites).

The Spatial Simulation Model is flexible in that as additional data layers are generated, they can be easily incorporated into the model by copying and pasting an ArcView® grid data source into the relevant directory. In the case of this model, the original intention was water quality protection. There is nothing, however, that prevents the use of the model on other detailed data such as air quality or more detailed sedimentation data.

DEVELOPING GIS GRID DATA FOR SOIL EROSION INDEX

Which Soil Erosion Data?

For siting of new AFOs and land application sites, soil loss is a significant factor and needed to be included in the DSS. The question of how and what data would one present on a 50 m x 50 m grid? Originally, the k-factor in the soil erosion index equation taken from county soils data served as a good proxy for soil loss potential, thus creating 50 m x 50 m grids, each grid cell with a unique k-value.

At one stage, debate was raised as to whether the Spatial Simulation Model (within the context of the Decision Support System) should use soil loss grids based on the Universal Soil Loss Equation (USLE). In principle, this is possible given field boundaries, field coverage and conservation practices. In practice, acquisition of data regarding field vegetation coverage and conservation practices for an entire county (typically 5,000 fields) let alone a watershed, would be a practically impossible. Secondly, the slope length ([L], one of the parameters in USLE or RUSLE) which is a natural feature of the land is not bounded by any field boundary. It was thus decided that the Soil Erodibility Index would be the most suitable tool to represent erodibility for the entire county on a50 m x 50 m grid:

$$A = \frac{R \cdot K \cdot L \cdot S}{T} \qquad (1)$$

Where:

A = computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units selected for K and for the period selected for R (usually ton/acre/yr)
R = rainfall-runoff erosivity factor
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
T = soil loss tolerance

Building the Data layer

Among the five factors in equation 1, R was provided by the state NRCS office, while the K and T factors were acquired from Soil Survey Geographic Database (SSURGO) also provided by the state NRCS offices. The L and S factors were calculated from the Digital Elevation Model (DEM) data downloaded from the South Carolina Department of Natural Resources (SC DNR) web site [http://www.dnr.state.sc.us/water/nrima/gisdata]. DEM data are converted from hyspographic (contour) data into a grid of equally sized cells (typically also 50 m x 50 m), each cell representing a unique elevation.

The slope was derived from the DEM grid through the ArcView® Spatial Analyst® extension while the slope steepness factor (S) was calculated using the equation $S = 10.8 \sin q + 0.03$ (p. 107, USDA 1997), where q = aspect of the cell. Slope length, dependent on flow direction and within the confines of a 50 m x 50 m grid, may vary from 50 m (cardinal positions like N, S, E or W) to 70.70m (diagonal position like NE or SW etc.). For aspects other than those in cardinal positions, slope lengths were calculated from the aspect of the cell (derived from the DEM grid through ArcView® Spatial Analyst® extension) and the Law of Tangents using the following equation set:

$b = a \tan q$	When aspect is between 0-45 and 180-225
$b = a \tan(90 - q)$	When aspect is between 45-90 and 225-270
$b = a \tan(q - 90)$	When aspect is between 90-135 and 270-315
$b = a \tan(180 - q)$	When aspect is between 135-180 and 315-360

$$SlopeLength = 2 \cdot \sqrt{a^2 + b^2}$$

where a = 25m (for a 50 m grid cell), q = aspect of the cell. After calculating the slope length, slope length factor (L) was calculated using the following set of equations:

b = (sin$q$ /0.0896) / [3.0(sin$q$)$^{0.8}$ + 0.56] …….(p. 105, USDA 1997)

m = b / (1 + b) …….(p. 105, USDA 1997)

L = (l /72.6)^{m} …….(p. 105, USDA 1997)

Where q = slope angle and l = slope length in feet.

Advantages and Limitations

In the above procedure, slope steepness is more accurate than the slope length because slope length in a grid reference is bounded by the 50 m x 50 m grid cell. As the slope steepness factor is much more influential than the slope length factor in the soil loss equation, the procedure adopted here is seen advantageous. The limitation includes the process of finding slope length. Slope lengths are limited to a minimum of 50 m and a maximum of 70.70m, which in many cases simply does not correspond with reality. Given the limitations of the Spatial Simulation Model within the parameters of a DSS, we considered these limitations acceptable for a broad scale analysis that covers a minimum of one county.

Current Development

From a practical field-by-field application standpoint, the effect of vegetation cover and conservation practice factors simply cannot be ignored. To this end, a stand-alone application that calculates soil loss on a field-by-field basis is under development. The user will be able to use either the Universal Soil Loss Equation (USLE) or the Revised Universal Soil Loss Equation (RUSLE). The application will be driven by Visual Basic® forms, but will be launched from ArcView® upon the selection of a specific field. Note that for such an analysis to take place, the field needs to be digitized and represented in an ArcView® shape file.

CONCLUSIONS

The spatial simulation component of the GIS-based DSS has proved to be a valuable tool for evaluating any type of spatial data. In the current application, water quality is the prime focus. It is quite clear that any other spatially related data can be represented, and indeed, qualitatively or semi-qualitatively evaluated through the map algebra technique. The calculation of the Erosion Index is but one example of data that can be used, keeping in mind there will be limitations imposed by having to use equal-sized grids for the map algebra function. Soil loss (as opposed to soil erosion potential) can be calculated on a field by field basis from an ArcView® - defined field boundary. A standalone application to perform this function is currently under development to serve as a complementary, field-level tool to the DSS.

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COMPARISON OF FISH CATCHES FROM SEDIMENT DAMAGED RIVER ECOSYSTEMS

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INTRODUCTION

Channel incision, a lowering of channel base level via bed erosion, typically results in watershed destabilization. While a variety of causes can initiate channel incision, channel straightening of a naturally meandering river has been a common historical trigger (Shields et al. 1997). Several of the larger river systems in the hill-land region of the Yazoo River basin have been subjected to channelization. This activity has caused profound changes in the physical and geomorphological characteristics of these systems. Three of the rivers in this region have major problems resulting either directly or indirectly from channelization. Problems range from major blockages due to excessive sediment and debris accumulation to incision and over widening. In two cases the original channel has been reduced to a series of oxbow lakes and river cutoffs. In an attempt to compare the impact of these different problems on fish communities, fish were sampled by electroshocking gear and hoop nets. Fish species were separated into different functional groups based on flow preferences, food habits and habitat. Distinct differences were detected in the fish communities of the Yalobusha, Skuna and Tallahatchie Rivers based on these different functional groups. Lotic species dominated the fish communities within the open straight channelized reaches while lentic species preferred the quiescent areas above debris jams and cutoffs. This information may be useful in making comparison of damaged riverine ecosystems and assist managers in determining impairment and success in the Total Maximum Daily Load (TMDL) process.

MATERIALS AND METHODS

Fish were sampled by electroshocking gear and hoop nets from six river reaches representing five major habitat categories to determine differences in fish community structure. These reaches were located in one of three lowland rivers in the North Mississippi. Categories included: Channelized lentic, channelized lotic, channelized lotic damaged, un-channelized lotic, un-channelized lentic damaged (Table 1).

Two sections of the Yalobusha River were sampled. The first section, designated Lower Yalobusha, was a sinuous un-channelized river reach below a large sediment and debris blockage. This reach had a mean water depth of 3.5 m and velocities that ranged from 2 to 120 cm s-1. Bottom substrate was not sampled but probably consisted of sand based on observed velocities and upstream geology. The second study section, designated Upper Yalobusha, was a channelized reach upstream of the debris blockage and characterized by low velocities (7 to 21 cm s-1) and a mean depth of 1.7 m. The bottom substrate is primarily sand with local deposits of silty mud and clay and large woody debris. The Skuna River was characterized by extremely low depths (mean depth 0.2 m) and sandy substrate (93% sand). Mean velocity was 19 cm s-1 at the time of fish sampling. Large woody debris was scarce. Shallow depths, uniform substrate and lack of woody debris are typically indicators of ecologically damaged conditions (Shields et al. 2000).

Three sections of the Tallahatchie River were sampled. An un-channelized lotic section of the original river, designated Lower Tallahatchie, was the most natural with a wide range of depths and velocities (current 0 to 30 cm s-1). Deposits of sand and woody debris were plentiful along the banks. The bottom substrate was sand. Immediately upstream of the Lower Tallahatchie reach was a straight channelized river reach (Upper Tallahatchie, representing channelized lotic conditions) characterized with uniform widths and depths. Banks were steep and uniform and velocities were relatively swift (current ~40 cm s-1). Woody debris was virtually absent. In the process of excavating the channelized portion of the Tallahatchie a section of the original river channel was cut off from the current river channel. This section designated Old Tallahatchie was stagnant (current < 5 cm s-1) when we sampled it, with generally shallow depths. Large woody debris was plentiful, but was in the form of almost regular arrays of vertical, partially decomposed willow (Salix spp.) stumps, which lacked the complexity of typical formations composed of fallen trees. Depressed dissolved oxygen levels were observed during late summer even near the surface of one old river channel study site. Because of the uniformity of habitat and poor water quality this reach may also be considered ecologically damaged.

Fish were sampled using hoop nets and a boat-mounted electro-shocker. Fish were identified to the species level and lengths were measured. Weights of fish were either measured or estimated using length weight relationships developed for Mississippi fishes. Water quality parameters were measured in-situ using a YSI model 85 and Corning pH meter.

Table 1. A summary of sampling reach characteristics

River Reach	Condition	Mean Depth (m)	Velocity cm s^{-1}	Woody Debris	Substrate
Upper Yalobusha	Channelized Lentic	1.7	7 - 21	Yes	Sand/Clay
Lower Yalobusha	Un-channelized Lotic	3.5	2 - 120	Yes	Sand
Skuna	Channelized Lotic Damaged	0.2	19	No	Sand
Lower Tallahatchie	Un-channelized Lotic	1 - 4	0 - 30	Yes	Sand
Upper Tallahatchie	Channelized Lotic	1 - 2	~ 40	No	Sand
Old Tallahatchie River	Un-channelized Lentic Damaged	1 - 2	< 5	Yes	Clay

RESULTS AND DISCUSSION

Fish catch and community characteristics for each river reach are summarized in Table 2 and Figure 1. A total of 2349 fish representing 43 species were collected in the 6 river reaches. The Upper Yalobusha had the greatest taxa richness with 31 species, while the Upper Tallahatchie had the lowest with 13. Skuna had the highest catch with 1025 fish, most of which were Blacktail shiners. Catches from the two lentic reaches Upper Yalobusha and Old Tallahatchie River were dominated by suckers comprising 81 and 44% of the catch respectively. Minnows dominated the catches of the lotic reaches.

While distinct differences in the fish communities were evident, only the Skuna appeared to have characteristics of a damaged system. More than 95% of the catch was comprised of species reaching an adult length of less than 300 mm. The lotic omnivorous fishes that dominated the catch from Skuna are often associated with smaller stream rather than rivers. Furthermore 72% of the catch consisted of fish preferring littoral zone habitats. The shallow depth and lack of woody debris in Skuna provided a selective advantage for smaller species of fish that could use shoreline habitats as protection from the current.

Despite low oxygen concentrations the Old Tallahatchie River reach supported a diverse fish fauna, a balance of lentic and lotic species and a significant community of larger species. The only characteristic indicating possible ecological damage was the relativity low catch (171 specimens).

The two un-channelized reaches that might be expected to represent “natural” conditions had similar percentages of catch of fish attaining a length greater than 300mm, however Lower Tallahatchie had a higher percentage of lentic fish (77%). While there was some backwater effect on both Lower Tallahatchie and Lower Yalobusha from large flood control reservoirs downstream of the reaches, the backwater effect was probably more pronounced on Lower Tallahatchie thus providing habitat for a higher percentage of lentic fishes. Both reaches supported gizzard shad, which are pelagic planktovores and typically found in large impoundments.

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Table 2. Species list and catch from each sampling reach

Common	Genus	Species	Upper Yallobusha	Lower Yalobusha	Skuna	Lower Tallahatchie	Upper Tallahatchie	Old Talahatchie River
Bowfin	*Amia*	*calva*		1				2
Pirate Perch	*Aphredoderus*	*sayanus*			1			
Brook Silversides	*Labidesthes*	*sicculus*		5				1
River Carpsucker	*Carpiodes*	*carpio*				2	1	5
Smallmouth Buffalo	*Ictiobus*	*bubalus*	419	35	1	4	5	59
Bigmouth Buffalo	*Ictiobus*	*cyprinellus*	2	49				2
Black Buffalo	*Ictiobus*	*niger*				4		9
Spotted Sucker	*Minytrema*	*melanops*		1				
Green Sunfish	*Lepomis*	*cyanellus*		3	11			
Warmouth	*Lepomis*	*gulosus*	1	2	2			2
Orange Spotted Sun	*Lepomis*	*humilis*		4				
Bluegill	*Lepomis*	*macrochirus*		29	95	6		24
Longear Sunfish	*Lepomis*	*megalotis*			14			
Redear Sunfish	*Lepomis*	*microlophus*		3				2
Spotted Bass	*Micropterus*	*punctulatus*	1		5			
White Crappie	*Pomoxis*	*annularis*	1	4		1	1	19
Black Crappie	*Pomoxis*	*Nigromaculatus*	2	1				1
Gizzard Shad	*Dorosoma*	*cepedianum*	4	38		8	1	4
Bluntface Shiner	*Cyprinella*	*camura*			1			
Blacktail Shiner	*Cyprinella*	*venusta*	3	90	626	7	3	1
Common Carp	*Cyprinus*	*carpio*	18	38		3	4	8
Ribbon Shiner	*Lythrurus*	*fumeus*		12				
Redfin Shiner	*Lythrurus*	*umbratilis*		52				
Emerald Shiner	*Notropis*	*atherinoides*	25	18		31	11	
Ghost Shiner	*Notropis*	*buchanani*		1				
Yazoo Shiner	*Notropis*	*rafinesquei*			128			
Pugnose Minnow	*Opsopoeodus*	*emiliae*		1				
Bluntnose Minnow	*Pimephales*	*notatus*		1				
Bullhead Minnow	*Pimephales*	*vigilax*		5	8			
Grass Pickerel	*Esox*	*americanus*		3				
Blackstripe Topmin	*Fundulus*	*notatus*			1			
Blackspotted Topmin	*Fundulus*	*olivaceus*	1					
Yellow Bullhead	*Ameiurus*	*natalis*		3				1
Blue Catfish	*Ictalurus*	*furcatus*		2		2	1	
Channel Catfish	*Ictalurus*	*punctatus*	9	37	18	1	8	1
Flathead Catfish	*Pylodictis*	*olivaris*	13	5	1			
Spotted Gar	*Lepisosteus*	*oculatus*	6	19	9	2	2	13
Longnose Gar	*Lepisosteus*	*osseus*	3	39		1	11	7
Shortnose Gar	*Lepisosteus*	*platostomus*	6					
White Bass	*Morone*	*chrysops*	5				2	
Dusky Darter	*Percina*	*sciera*				1		
Mosquito Fish	*Gambusia*	*affinis*		2	104			
Freshwater Drum	*Aplodinotus*	*grunniens*	3	2		1	2	10

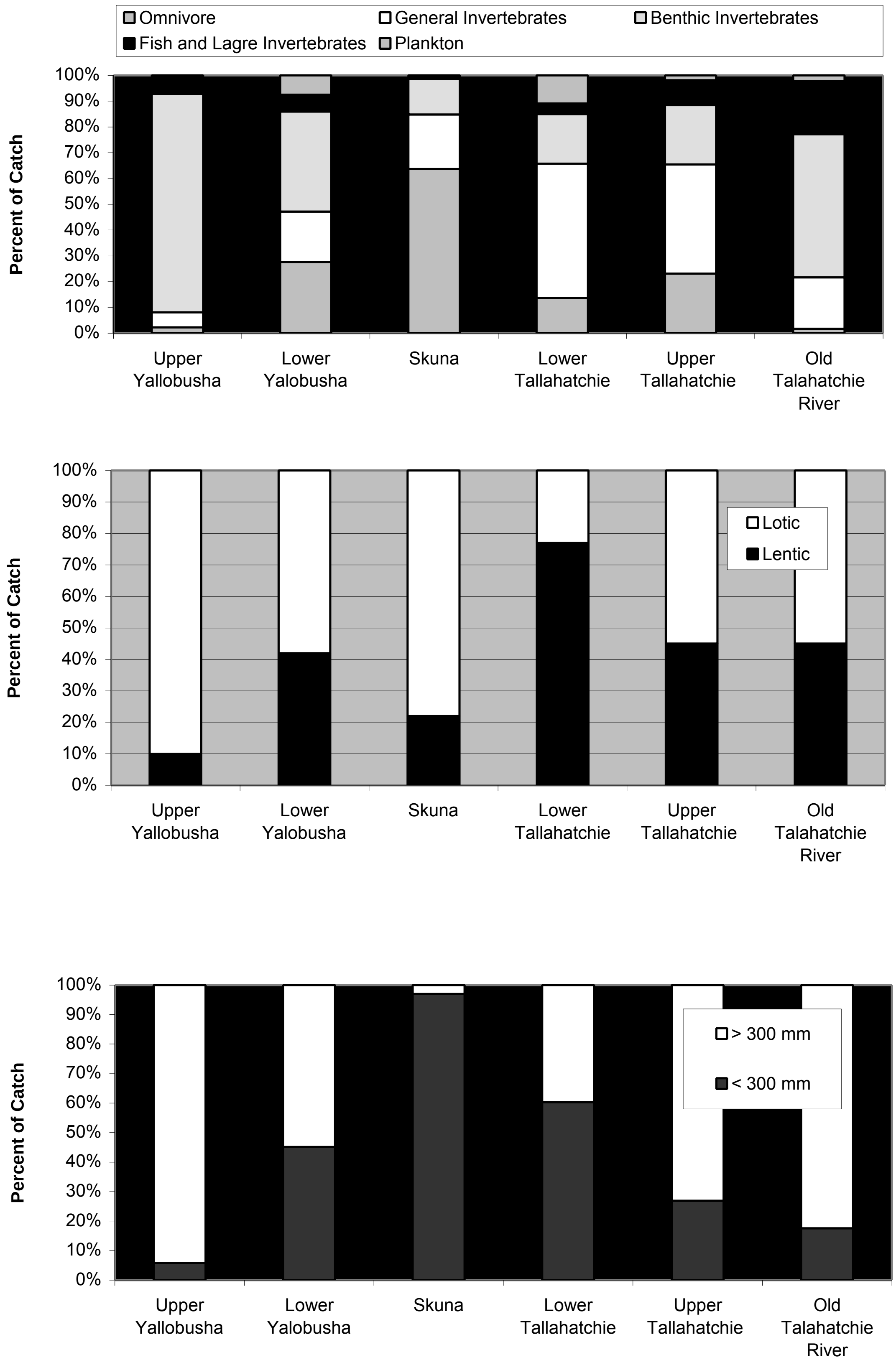

Figure 1. Percent of catch by feeding group, flow preference and maximum adult size of fish communities from selected sections three Mississippi Rivers.

SUSPENDED SEDIMENT ANALYSIS OF THE TRUCKEE RIVER BASIN IN SUPPORT OF A TMDL DELINEATION

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ABSTRACT

In accordance with Section 303(d) of the Clean Water Act, the Lahontan Regional Water Quality Control Board (LRWQCB) of the California Department of Environmental Protection has ascertained that reaches of the Truckee River and a number of its tributaries in California are water quality limited for sediment, nutrients, total dissolved solids and chloride. The water quality of the river system has been impacted by a variety of sources, including forest management, urban and recreational development, hydromodification and other alterations of wetland and fisheries habitat. In order to meet the conditions of the beneficial uses of the Truckee River, the study focused on determining the necessary reduction of sediment loading from specific sub-watersheds in the basin to the waterbody.

Suspended sediment was monitored for the major tributaries to the Truckee River for the period of snowmelt runoff during the spring and summer of 2000. The major tributaries monitored include: Bear Creek, Squaw Creek, Pole Creek, Donner Creek, Trout Creek, Juniper Creek, Gray Creek and Bronco Creek. Inputs from those tributaries (except Martis Creek) which contained watershed impoundments were neglected, as it was assumed that reservoirs would function as a sediment sink. Depth integrated samples for suspended sediment were collected utilizing standard U. S. Geological Survey methodology (according to Edwards and Glysson 1999) at or near the outlet of the tributaries utilizing a DH-81 sampler.

Duplicate samples were taken at regular intervals in order to compute the error associated to sampling methodology. Flow measurements taken (according to U.S. Bureau of Reclamation 1981) at the time of sampling allowed for the regression of sediment concentration (mg/l) against discharge (cfs). Comparison of the slopes of the regression equations within significantly impacted sub-watersheds to those of control streams or reaches (selected within the Truckee

River basin so as to minimze climatic and geologic variability) revealed that such an ecosystem approach may be used to evaluate watershed conditions and can serve as a valuable tool for quantification of numeric targets associated with sediment TMDLs. Specific numeric targets and future monitoring protocol are presented. Furthermore, the relationship between total suspended solids, nutrients, total dissolved solids and chloride is discussed.

THE PHOTO-ELECTRONIC EROSION PIN (PEEP) AUTOMATIC EROSION MONITORING SYSTEM: PRINCIPLES AND APPLICATIONS

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Abstract: This paper describes the PEEP (Photo-Electronic Erosion Pin) automatic erosion and deposition monitoring system, developed originally for river bank erosion applications, but now extended to other contexts. It generates quasi-continuous data on the magnitude, frequency and timing of individual erosion and deposition events, rather than the temporally-aggregated information obtained with conventional methods. PEEP measurement principle, design, calibration and usage are briefly outlined, together with two example applications to erosion and deposition monitoring on UK river banks.

INTRODUCTION

The absence of an appropriate automatic system for bank erosion monitoring has inhibited the collection of reliable field data on the precise timing, magnitude and frequency of erosional and depositional activity. Traditional, manual, techniques (e.g. erosion pins or resurvey techniques; Lawler, 1993) simply reveal net change to the bank or gully face since the previous measurement. Only rarely can they reveal the temporal distribution of that change within any given measurement interval, in response to transient fluctuations in the driving forces (e.g. floods, rainstorms, freeze-thaw events or tidal cycles). This brief paper describes the novel Photo-Electronic Erosion Pin (PEEP) system designed to address some of these problems. It focuses on the PEEP measurement principle, instrument design, and calibration and installation procedures. It closes with two example erosion and deposition events to illustrate the effectiveness of the method and the benefits to monitoring agencies and research and management institutions.

PEEP MEASUREMENT PRINCIPLE

The PEEP sensor is a simple, light-sensitive, optoelectronic instrument for the automatic monitoring of erosion and deposition events and rates on river banks, gully walls, hillslopes, beaches, tidal channels etc. It consists of a waterproofed, transparent, acrylic tube which contains an array of upward-looking photovoltaic cells connected in series and mounted on a printed circuit board (see Lawler et al., 2001, this volume). This cell series outputs a simple analogue millivolt (mV) signal proportional to incident light, which is continuously recorded by a datalogger.

PEEP sensors are inserted into an eroding river bank or sediment surface, much like conventional erosion pins, and are connected by cable to a nearby datalogger or PC (Lawler et al., 2001, Fig. 1, this volume). Subsequent retreat of the bank/soil face exposes more photosensitive material to light: this increases PEEP mV outputs. Accretion causes photovoltaic outputs to drop. Subsequent scrutiny of the logged signals for peaks, ramps and troughs in PEEP outputs consequently reveal the magnitude, frequency and timing of erosion and deposition events much more precisely than has been possible hitherto. Typical resolution is approximately +/- 2-4 mm, depending on light and site conditions. Twelve research groups and monitoring agencies around the world are now using the PEEP system for erosion and deposition monitoring, including in the USA, England, Wales, Australia, Denmark and Malaysia.

PEEP SENSOR DESIGN

The tubes for current PEEP models are 66 cm long and 16 mm O.D (12 mm I.D.), although virtually any length is possible to fit the application. The standard 'active length' (i.e. that part of the tube lined with photovoltaic cells) is 200 mm: this can also be varied to suit. The individual photovoltaic cells are mounted sufficiently close together to ensure that their 120^{o} windows overlap: this gives a continuous and sensitive response when the tube is progressively exposed by erosion (see Lawler et al., 2001, Fig. 1, this volume).

The photovoltaic cells used are designed for optical instrumentation purposes and are highly sensitive. Their spectral sensitivity lies in the visible light and in the near infra-red range. Two additional reference cells, at either end of the array, allow PEEP output signals to be normalised for changing ambient illumination. The photovoltaic signals can also be used for direct monitoring of light intensity on the eroding/accreting face: this can be useful in helping to explain biological processes - such as vegetation growth - which influence the erosional intensities. PEEP sensors do not require a power supply, because PEEP *photovoltaic* cells convert incident light directly into an electrical signal.

Also, because the sensors also contain two thermistors, one near the sediment surface and one 68 mm below, PEEPs can also be used to monitor sediment temperature and temperature gradients. This, too, can provide useful information pertinent to the erosion or deposition study (e.g. freeze-thaw or desiccation activity on the soil face, or thermally-driven biological processes). Furthermore, incorporation of two thermistors allows the timing of some erosion events to be further fine-tuned using *thermal consonance timing* (see Lawler et al., 2001, this volume). Like any instrument, the PEEP sensor is not without limitations (e.g. see Lawler et al., 1997a, 2001 this volume). For example, because it depends for its operation on visible light, unless an artificial light source is added, PEEPs do not detect *nocturnal* activity until the following morning when the instrument is reactivated by daylight.

PEEP CALIBRATION PROCEDURES

PEEP sensors are designed so that 1mm of extra tube exposure increases the output by ~1mV. Laboratory calibrations are performed using a simple rig consisting of a light-tight box with a 16mm hole in one end through which the PEEP sensor is pulled along a graduated track. This allows known amounts of incremental PEEP exposure to be related to sensor mV outputs. The linear trend is fitted with a least squares regression equation thus:

$$L = c + d.Rpp \qquad (1)$$

where Rpp (%) = (V_{cs} / V_{rc}) x 100, V_{cs} is the cell series voltage output (mV), V_{rc} is the reference cell output (mV), and coefficients *c* and *d* are determined from the least-squares regression.

There is a strong linear association between *L* and *Rpp*, and typical r^2 values exceed 99.9%. Low standard errors of estimated tube length (~1.1 mm; Lawler, 1992) means that, under calibration conditions, tube exposure can normally be estimated with 95% confidence to ± 2.2 mm. In practice, of course, where field illumination conditions are more complex and less stable, the position of the sediment surface is usually known to ± 2-4 mm. Furthermore, field and site-specific calibrations can be gradually built up over the course of the study by relating actual PEEP outputs to lengths of exposed PEEP tube measured at the time of each field visit. Using dataloggers to store the average of several scans can also increase the resolution of the measurement.

INSTALLATION PROCESS

PEEPs are normally installed horizontally into near-vertical faces like river banks or gully walls, or vertically into near-horizontal surface like tidal mudflats, saltmarshes or low-angles hillslopes. Usually, a small-diameter hole is carefully augered in the bank to accept the PEEP tube. It is made long enough to accommodate any future re-setting of the sensor that may be necessary as erosion proceeds, much like the erosion pin. For river bank applications, the cable is taken out of the back of the sensor through the bank interior and up to the floodplain (Lawler, 1992; Lawler et al., 2001 this volume). This prevents fouling of the delicate bank surface by a flapping cable. It is common for networks of PEEP sensors (e.g. 2-12) to be installed at a single site to account for spatial variability in erosion rates.

EXAMPLE APPLICATIONS: EROSION AND DEPOSITION EVENTS

Brief results from early-generation PEEP models on UK river bank sites demonstrate the advantages of the system in monitoring the magnitude and timing of individual erosion and deposition events. This information, in relation to data on the incidence of high-flow events, rainstorms, pore water pressure increases and other influential variables, is crucial to understanding the processes involved.

The first example, drawn from the Plynlimon site on the Upper River Severn in mid-Wales, UK (at this point a small upland stream), demonstrates how the PEEP system can determine the timing of a delayed bank erosion event (Fig. 1). Note how the diurnal pattern of PEEP cell series outputs rises sharply on December 22, 1990 at precisely 13.30 h GMT. This confirms that a bank erosion event of at least 80mm has taken place at this time - 43 hours after the flow peak (Fig. 1). Knowledge of event timing is crucial to strong process inference. Delayed bank retreat, for example, implies that mass failure processes were more important than boundary shear stresses on this occasion.

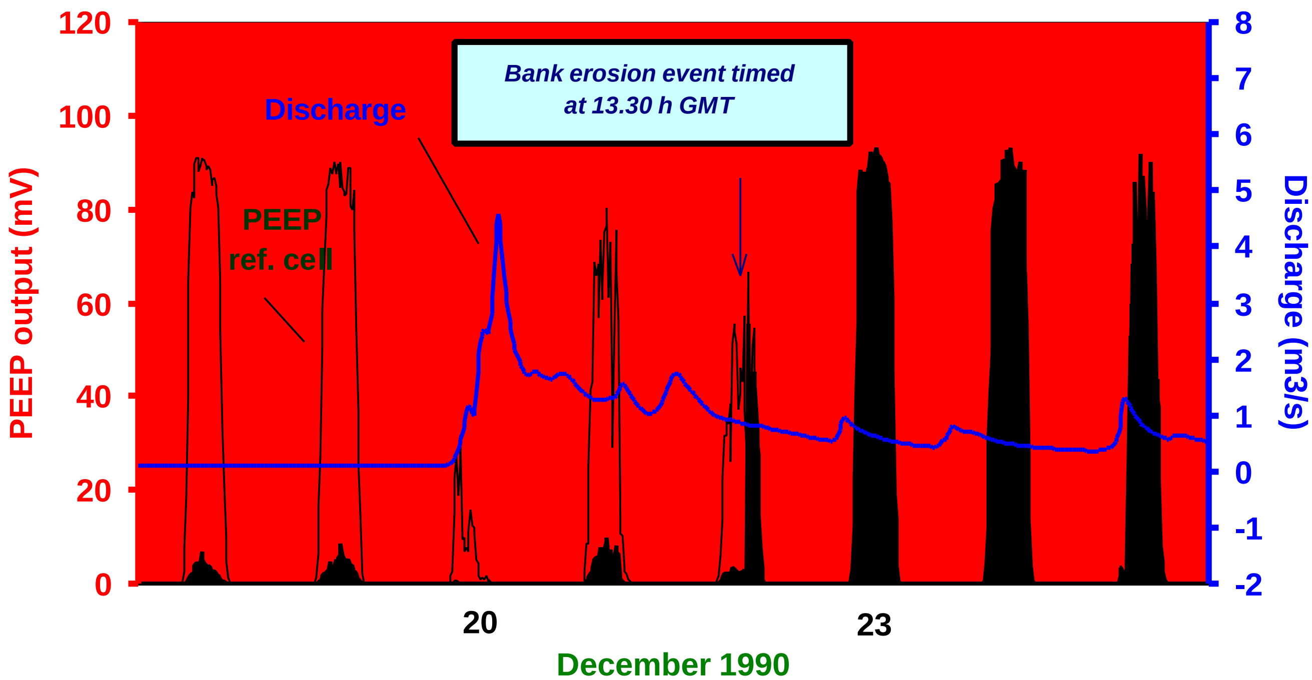

Figure 1. A delayed bank erosion event detected by a PEEP sensor on the Upper River Severn in mid-Wales, UK, on 22 December 1990 at 13.30 h GMT - 43 hours after the flood peak.

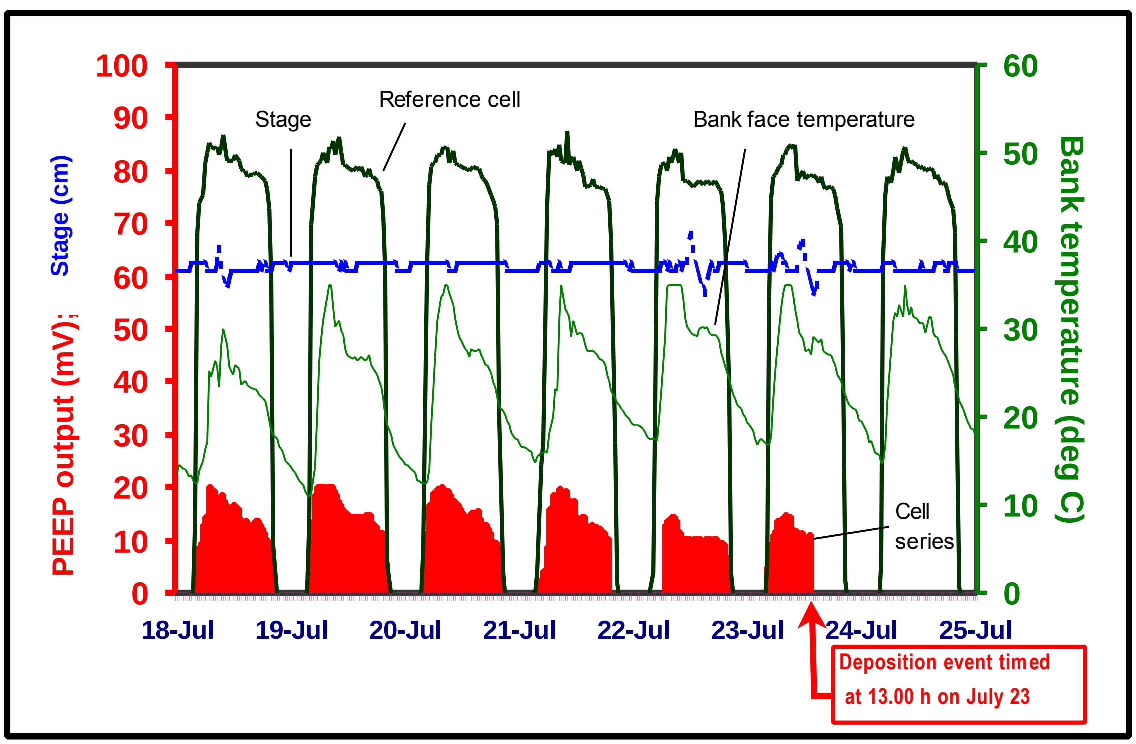

Figure 2. Example deposition event recorded by a lower-bank PEEP in July 1989 on the R. Arrow, central England, as a result of desiccation spalling of material from above

The second example, from the lowland River Arrow in central England, shows how the PEEP sensor can define the magnitude and timing of a *deposition* event (Fig. 2). This time, a sharp *drop* in the PEEP cell series signal on July 23 at 13.00h GMT, relative to a largely constant series of diurnal reference cell outputs, indicates the precise moment that sediment has been deposited here. The depth of accretion is 10 mm - insufficient to bury the whole PEEP, as shown by unchanging reference cell signals (Fig. 2). The fact that, as Fig. 2 shows, this event occurred under low and stable flow levels, following a period of very high bank face temperatures in summer (daily peaks > 35°C), indicates that desiccation spalling of the bank surface higher up the bank caused material to collect on the lower bank slopes. Subsequent field inspection confirmed that vigorous desiccation cracking of the upper bank had indeed generated a sheet of loose aggregates across the entire bank toe zone just above the waterline (Lawler, 1992).

Further examples of PEEP system applications to bank erosion problems can be found in Lawler (1992, 1994; Lawler et al., 1997a, 1997b, 2001 this volume; Mitchell et al., 1999; Prosser et al., 2000; Stott, 1999).

CONCLUSIONS

The PEEP system, being *automatic*, helps to deliver clearer pictures of the actual temporal distribution of erosional and depositional activity in a variety of contexts. This information is vital to understand erosion dynamics and processes, and allows more comprehensive analyses of relationships between controlling variables and erosional response. In particular, it should now be possible to: identify erosion thresholds more definitely; undertake magnitude-frequency analyses more comprehensively given that the geomorphological impact of individual, rather than aggregated, flow (and other) events can be determined; and test erosion/deposition models more effectively.

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ABSTRACT

Poster Session

Rio Grande Geomorphology Study
San Acacia, New Mexico to the Narrows of Elephant Butte Reservoir

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topic: Geomorphology; poster session

One purpose of the Rio Grande Geomorphology Study is to identify and quantify historic geomorphic responses, such as channel width and sinuosity, to natural and man-induced changes in hydrology, channelization, vegetation management, impoundment, and sediment management. This segment of the study addresses the Middle Rio Grande from San Acacia, New Mexico to the Narrows of Elephant Butte Reservoir.

The Middle Rio Grande has been undergoing a general aggradation trend throughout its history. This aggradation, combined with flood events, has caused the river to experience periodic avulsions and corresponding channel location changes. GIS was used to compare and quantify changes in river planform over time using digitized survey data from 1918 to 1992. The GIS database was a useful tool which allowed visualization of the impacts.

The study quantified the results of some of these impacts and will help provide guidance for future river management activities. Specifically, the identification of equations to describe the relationship between discharge and width enabled the comparison of river width in a variety of management scenarios. The results may be used to minimize aggradation/degradation impacts and maximize water delivery, water conservation, and habitat management goals.

QUANTITATIVE ASSESSMENT OF EROSION AND SEDIMENTATION EFFECTS OF FOREST MANAGEMENT IN NORTHERN CALIFORNIA

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Concerns regarding potential cumulative watershed effects associated with erosion and sedimentation from management activities must frequently be addressed in environmental impact assessments. The scope of management activities may range from a single timber harvest plan to a habitat conservation plan affecting multiple watersheds. Quantitative assessment is necessary to evaluate land management impacts on the timing and magnitude of erosion and sedimentation processes and to increase the depth of knowledge needed by land managers, regulatory agencies, policy makers, and the public to develop appropriate mitigation. Sediment budget techniques can be used to develop a practical quantitative analysis suitable for watershed environmental assessments.

Sediment budget techniques include a variety of approaches to quantify erosion, transport, and deposition of sediment at a variety of spatial and temporal scales. Once particularly useful conceptual model for sediment routing in stream systems comes from reservoir theory. Sediment grains in storage in a river channel are stored in "reservoirs" with distinctive characteristics such as the active channel bed and bars, semi-active vegetated terraces, and inactive terraces. Sediment is transferred between reservoirs by fluvial processes. A variety of approaches have been employed to quantify the rates of transfer among reservoirs and the rate of movement downstream. The critical data to assess sediment routing in this manner are sediment storage volumes, sediment transport rates, and transfer rates among reservoirs. Sediment attrition rates may also be important. The objective is to estimate the residence time of sediment in various portions of the watershed, thereby providing a quantitative assessment of sediment routing processes.

Sediment storage volumes in stream channels are relatively easy to estimate by observation in the field. In channels that may be extensively aggraded or sand-bedded, this may be more difficult, but minimum estimates are nevertheless achievable. Sediment transport rates are considerably more difficult to obtain, but many approaches will yield usefull estimates. These include a literature search for regional sediment yield data and development of a sediment input budget for the watershed. These data can be normalized to a per unit watershed area value, and extrapolated to locations of interest as a function of drainage area. A second approach is for the area of interest. The assumption can then be made that watershed sediment inputs are equal to sediment outputs, thereby providing an estimate of sediment yield that can be normalized to quantity per unit watershed area per unit time. This estimate of yield can then be converted to an average sediment transport rate for a given watershed location.

Supplemental analyses include application of sediment transport equations at selected locations in the watershed. It is necessary to survey channel cross-section, develop hydraulic analyses for flow stages of interest, and apply appropriate sediment transport equations. Development of a hydrologic model that generates hydrographs for cross-sections of interest may be warranted. Finally, field measurements of sediment transport during just a few peak flows wouls significantly improve accuracy of the hydraulic analyses.

USGS EAST-COAST MARINE SEDIMENT DATA ON CD-ROM

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Abstract: Starting in 1962, the U.S. Geological Survey (USGS) began an extensive program to study the marine geology of the continental margin off the Atlantic coast of the United States and adjacent waters. As part of this program and numerous subsequent projects, thousands of sediment samples were collected and analyzed for grain size. We have compiled, edited, and integrated the textural methods and digitally available sediment data produced by the USGS projects based in Woods Hole, Massachusetts, constructed georeferenced displays of these data, and released this information on CD-ROM. The sediment database of the Coastal and Marine Geology (CMG) Program is currently being developed and merged with data from other federal agencies in an Access relational database as part of the USGS-CMG Aggregates Project.

INTRODUCTION

Many scientific questions and policy issues related to the offshore require sediment data of historical and regional scope. Because existent data are often widely dispersed and not always accessible and because acquisition of new data is expensive, existing data need to be utilized and serve as a foundation for further work. The purpose of the CD-ROM described herein is to present the field methods used to collect the USGS east-coast marine sediment samples and the laboratory methods used to determine and characterize the grain-size distributions and to provide the sediment data with metadata in three flat-file formats that can be readily employed by interested parties. To these ends, the report is comprised of three sections: the first discusses procedures, the second contains the data, and the third provides the ability to use desktop geographic mapping tools to visualize the sediment distributions. The contents of this CD-ROM are verified and well documented and, as such, provide the first step for environmental managers, policy-makers, scientific researchers, and interested members of the public to gain access to this information.

PROCEDURES

The procedures section describes field methods used to collect marine sediment samples and laboratory methods used to determine and characterize their grain-size distributions. The field methods section contains recommended sampling, handling, and storage protocols and a pictorial gallery of common sampling devices covering grabs, corers, dredges, bedload samplers, and sediment traps. The section on laboratory methods contains analytical flow diagrams, instructional video clips with voice commentaries, pictures and schematics of the analytical equipment, classification schemes for grade scale and nomenclature, comments on quality assurance, useful forms, and compiled and uncompiled versions of the data-acquisition and data-processing software with documentation and system requirements.

DATABASE

The sediment database incorporates information on the collection, location, description, and texture of samples taken by numerous marine sampling programs, most of which are from off the east coast of the United States. The database presently contains data for over 18,000 samples, which includes texture data for approximately 3,800 samples taken or analyzed by the Atlantic Continental Margin Program, a joint USGS/Woods Hole Oceanographic Institution project conducted from 1962 to 1970 (Emery and Schlee, 1963; Hathaway, 1971). Texture data for approximately 14,500 samples analyzed by the USGS-CMG Sediment Laboratory in Woods Hole, MA, after 1980 make up the rest of the database. Although most records contain complete grain size analyses, some are simple bottom descriptions from rocky and bouldery locations where samples were not taken. Most of the samples were collected with some type of grab sampler; however, a few were obtained by coring.

Database Platform and Formats The basic structure of the sediment database is a matrix where records are rows representing individual samples and the columns contain information on sample identification, navigation, classifications, analyzed parameters, and comments. This is a "flat-file" format, which means that it is not "normalized". While this is considered inefficient from the point of view of database management, it is the simplest way of presenting the basic data. This structure was chosen to avoid ambiguity, and to make the process of locating fields, entering data, and validating it simple yet comprehensive. Since neither the software capabilities of the user nor the probable uses of the data were known, no attempt was made to split the files, to reduce blank fields, or to remove redundancies. The same data may be presented in more than one form (e.g. phi class frequency percents and cumulative frequency percents). Even though each form can be derived from the other, presenting both eliminates the need for the user to program formulas to calculate one from the other. Although this may violate the principal of having a single entry for any given data item, it greatly simplifies the use of the file. If the user wishes to make the data base more efficient through "normalization", we feel that it is better that this be done by the user to fit both the applications available to the user and the database structural logic that is familiar to the user. The price paid for the "flat-file" approach is additional storage space, exceptionally wide records, and the possibility that corrections made here at the source may fail to be carried through to all forms of the data affected.

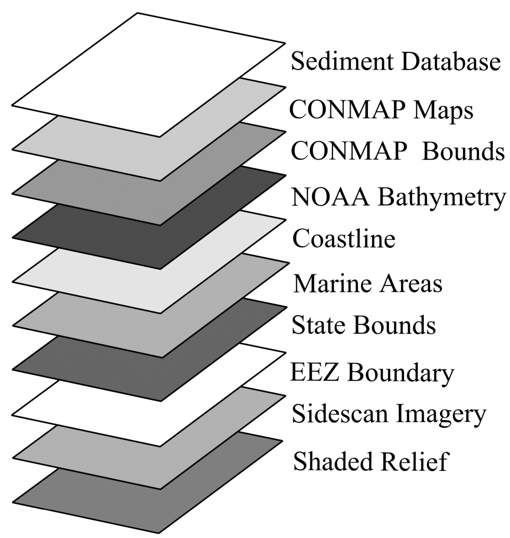
The database is provided in three formats: two popular software formats and one delimited ASCII text format. All were created in Microsoft Excel, 5.0/95. The formatted files (Microsoft Excel and Dbase IV) will open in the appropriate software if the user has the applications installed and their web browser properly configured. The tab-delimited file contains data as well as headings for the tables of data in uncompressed ASCII format. This file is supplied for users who do not have a DOS or Windows compatible computer, or for users who wish to import the data into unaccommodated applications that can accept ASCII character information. The database contains 98 fields and is supplied with a data dictionary that explains the structure and content of the database. It contains an index and definitions of the parameters measured and lists the fields which record and qualify those parameters. Extracting data from the database is facilitated by reference to this document because it provides a means to keep track of abbreviations and the sediment fields names. The specific fields and parameters have been chosen based on the USGS data produced Woods Hole and the format of information typically found in the literature. Most of the samples do not have data in all of the given fields; however, additional fields, qualifiers, and data can be added in virtually unlimited fashion to accommodate specific needs.

GEOREFERENCED DISPLAYS

Data layers were provided as georeferenced displays to provide users with the ability to visualize the textural information in a geographic context, to provide maps in flexible scales for synthesis, and to give the user the ability to identify and query geographic and attribute data (Polloni and others, 1995; Polloni, 1998). The primary effort was to deliver the textural data as geo-referenced points so that they could be used on basemaps for other digital data from along the U.S. east coast. The included project file has the inter-disciplinary data layers loaded as theme coverages (Fig. 1). The user can turn data layers on or off, measure distances, and add other user specified themes as long as they are in the same coordinate system. Coverages in state plane or other coordinate systems must be re-projected to be compatible with these data.

apping Tools and Data Layers Although the data assembled on this CD-ROM comes from a variety of sources, we have translated the data layers (Fig. 1) to be compatible with the Environmental Systems Research Institute (ESRI) desktop mapping tools ArcExplorer and ArcView, and have included separate project files for both tools. ArcExplorer software is supplied on the CD-ROM so that a user with a compatible operating system can down-load it to their own system and use it to display the coverages provided. ArcExplorer is compatible with ArcView and has the ability to link to coverages on the CD-ROM and also, if connected to the WWW, to coverages which may be available on GIS web servers. A manual for ArcExplorer is also provided in Adobe Acrobat (PDF) format. All data can be queried and has an attached metadata file for source and quality definition.

Figure 1. Data layers available on the USGS East-Coast Sediment Analysis CD-ROM.



Data Layers on this CD-ROM include: the USGS East-Coast Sediment Database, and, for regional reference purposes, the Continental Margin Mapping Project (CONMAP) series surficial-sediment maps, boundaries of the CONMAP series maps, National Ocean Service bathymetry, coastline, marine geographic areas from Hathaway (1971), state boundaries, the Exclusive Economic Zone boundary, GLORIA sidescan sonar imagery, and a shaded relief map of the conterminous United States (Fig. 1). The sediment maps in the CONMAP series, which were originally produced as part of the USGS Continental Margin Mapping Project (Klitgord and

Hill, 1986; Poppe and others, 1990; Poppe and others, 1994), are a syntheses of surficial sediment studies compiled of from grain-size data produced in the USGS-CMG sediment laboratory and from earlier published and unpublished studies. Although old and inaccurate at small scales, the CONMAP data layer is provided as a general overview to show gross textural trends.

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FLOW REGIMES NEEDED TO MAINTAIN CHANNELS IN GRAVEL-BED RIVERS

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Abstract: A range of moderate to high flows that occur less than 10 percent of the year can effectively maintain the physical features of gravel-bed channels. The typical channel maintenance hydrograph includes a range of discharges making up a portion of the rising and falling limbs of the annual hydrograph. Conceptually, the required maintenance flow regime begins at a discharge at which hydraulically limited gravels begin to move and includes all flows up to and including the instantaneous 25-year flow. Flows are needed for the duration during which they naturally occur. Flow years that fail to attain the threshold for hydraulically limited gravels are unnecessary for channel maintenance.

INTRODUCTION

Natural self-maintaining channels are a desirable feature of streams on the National Forest. In order to fulfill the primary National Forest purpose of "securing favorable conditions of water flows," the Forest Service seeks to establish non-consumptive channel maintenance instream flows. These flows, coupled with proper management of upland watersheds, will provide favorable conditions of water flows as intended by the Organic Act of 1897. After serving public needs on the National Forest, all this streamflow becomes available to downstream users under state law to meet designated beneficial uses.

The Forest Service must retain essential instream flows that convey sediment because future offstream uses such as irrigation, municipal water supplies, or other legitimate uses may deplete these flows. When essential instream flow is removed, sediment accumulates in the channel because the reduced flows cannot transport the sediment load received. The channel responds by altering its size, morphology, meander pattern, rate of migration, stream-bed elevation, bed-material composition, floodplain morphology, and/or streamside vegetation. These channel alterations are frequently detrimental to favorable flow and sediment conveyance. The channel adjustment and vegetation ingrowth can constrict the channel, resulting in more frequent inundation of the floodplain by high flows.

SUMMARY OF SCIENTIFIC BASIS

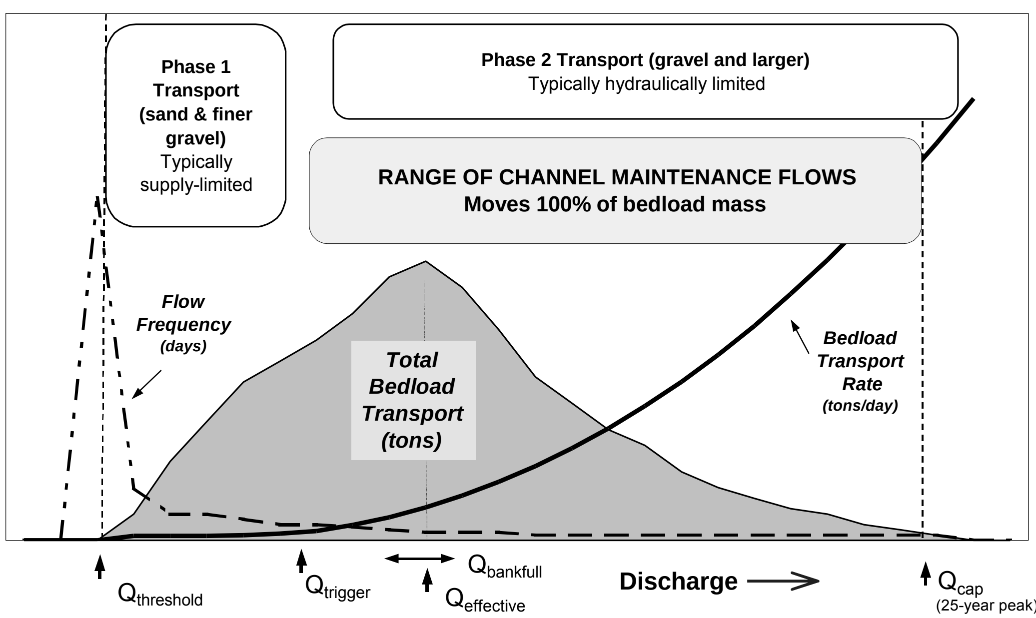
In developing this channel maintenance approach, we have applied current scientific knowledge and will continue to refine our approach as knowledge about flows and their relationship to ecosystems improve.

Sediment and vegetation have separate and combined influences on channel maintenance processes. The proposed approach has two major components: A bedload sediment transport component, and a streamside vegetation flow component.

The sediment transport component is required for every channel maintenance flow evaluation and is discussed here. The sediment transport component is primarily designed to move the required amount and sizes of sediment necessary to maintain channel capacity. Because these flows exceed bankfull stage, they may also scour vegetation from within the channel and periodically inundate portions of the floodplain thereby recharging aquifers and providing the disturbance required to sustain beneficial streamside vegetation. Generally, in temperate mountainous environments, where water accumulates at the base of slopes, the sediment transport component satisfies the vegetation regeneration and maintenance needs of streamside and floodplain vegetation.

The following figure illustrates the general model. The model requires streamflow and bedload transport data. The required instream flows begin with the initiation of Phase 2 bedload transport (Jackson and Beschta, 1982) up to the 25-year flow. A variety of techniques may be used to identify the beginning of Phase 2 transport including measured bedload samples, in-channel sediment traps, or analysis of bed material composition.

A General Model of Sediment Transport Processes for Channel Maintenance in Gravel-Bed Rivers



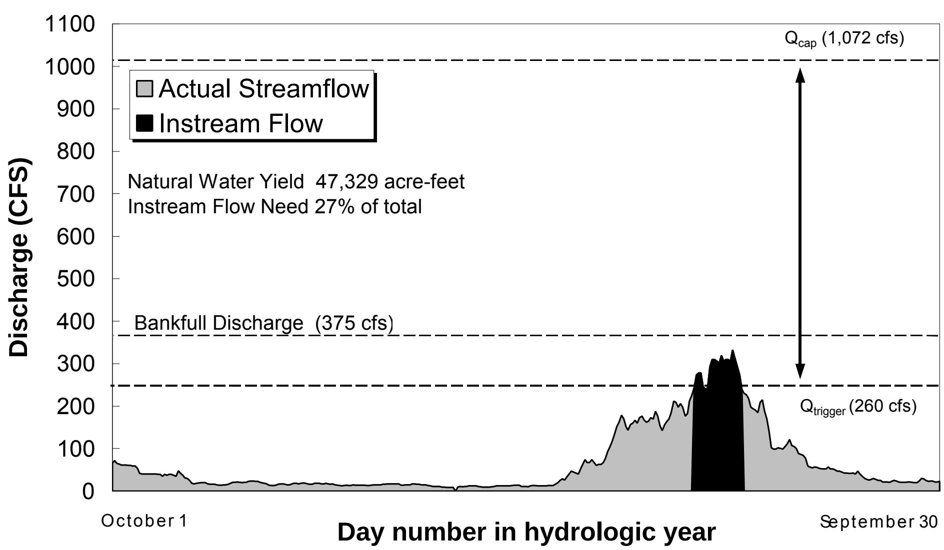
TYPICAL CHANNEL MAINTENANCE HYDROGRAPHS

The typical channel maintenance hydrograph includes a range of discharges making up a portion of the rising and falling limbs of the annual hydrograph. The instream flow hydrograph is initiated during the rising limb at a lower discharge ($Q_{trigger}$) and proceeds upward to an upper limit (Q_{cap}). The channel maintenance instream flow claim includes all flows greater than or equal to $Q_{trigger}$ and less than or equal to Q_{cap}. This range of flows includes bankfull discharge and effective discharge (Wolman and Miller, 1960). Conceptually, the required maintenance flow regime begins at a discharge at which hydraulically limited gravels begin to move (Phase 2 transport) and includes all flows up to and including the instantaneous 25-year flow (Q_{cap}). This range of flows is adequate to move all bedload sediment, scour vegetation, partially inundate the floodplain, and sustain streamside vegetation.

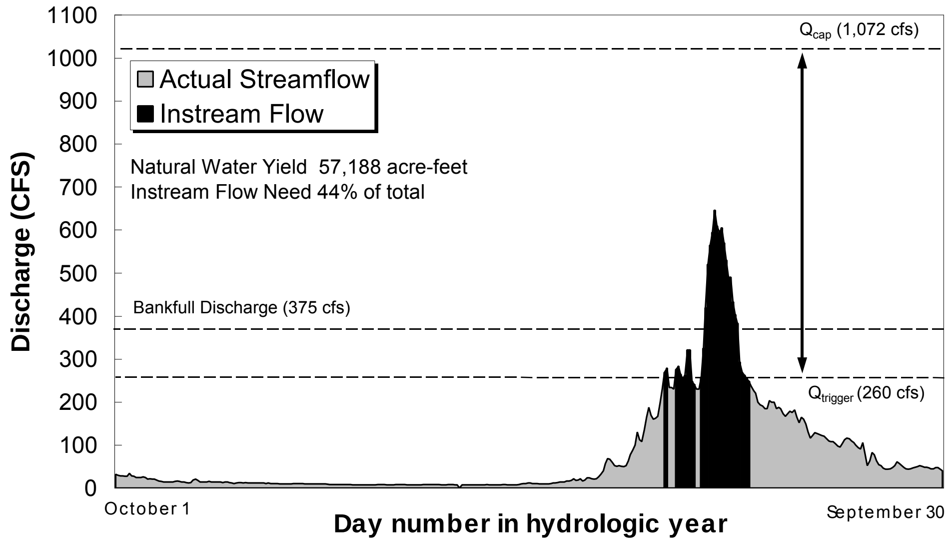
Flows are claimed for the duration during which they naturally occur. Generally, channel maintaining flows for a supply-limited gravel-bed river begin at flows ranging between 1/2 bankfull and bankfull. Bankfull often is approximated as the 1.5 to 2-year recurrence interval flow. The following figures provide one example that demonstrates typical bedload sediment transport component channel maintenance hydrographs for median (50% exceedence), above average (20% exceedence), and below average (80% exceedence) years.

The figures illustrate that the volume of water required for channel maintenance is highly variable from year to year, averaging about 30 to 40 percent of the annual flow volume. Since channel-maintaining flows rely on flow near and above bankfull, a high percentage of channel maintenance water needs are satisfied during wet years. During many low flow years, little to no water is required for channel maintenance.

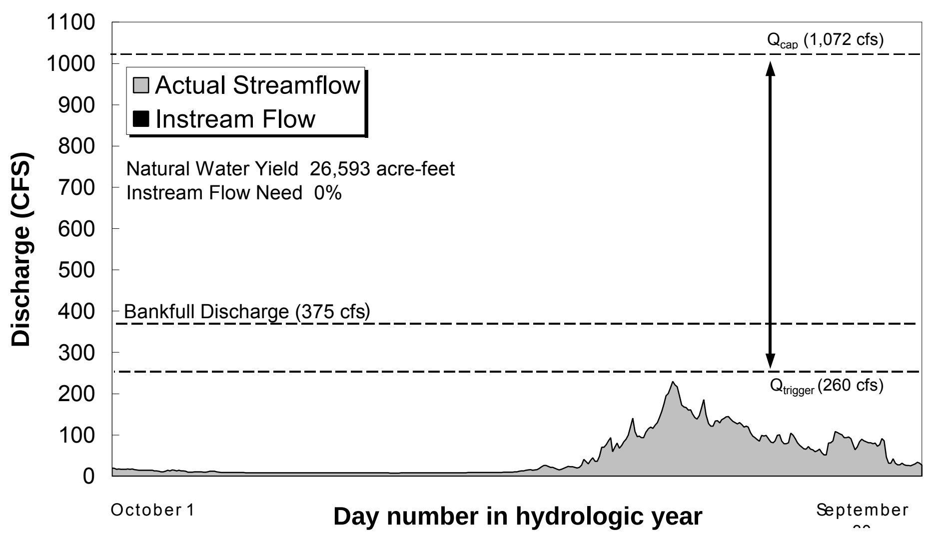
Typical Median Year Channel Maintenance Instream Flow
(Water Year 1962 - Flow Exceeded 50% of Years)



Typical Above Average Channel Maintenance Instream Flow
(Water Year 1971 - Flows Exceeded 20% of Years)



Typical Below Average Channel Maintenance Instream Flow
(Water Year 1976 - Flows Exceeded 80% of Years)



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USING AN UNDERWATER VIDEO CAMERA FOR OBSERVING BEDLOAD TRANSPORT IN MOUNTAIN STREAMS

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ABSTRACT: We investigated using an inexpensive underwater black and white video camera for viewing bedload sediment, including its movement and interaction with a Helley-Smith bedload sampler under a variety of flow conditions. Visibility of the stream bed and bedload particles was adequate at our maximum observed suspended sediment concentration of about 43 mg/l. The camera was well suited to viewing bedload sediments in low light conditions although the infrared capabilities of the camera were not adequate for use in total darkness. Entrained air bubbles in turbulent flows were the greatest impediment to viewing. Individual grains moving along the bed with a b-axis larger than about 15 mm were easily discerned and measurable on the screen. Smaller, high velocity saltating particles were difficult to see especially when viewing the video frame by frame. We were able to successfully measure and match particles observed on the video with those collected with a bedload sampler. With properly installed calibrating scales, the video camera system can be used to estimate particle size and transport in the larger size classes. While filming the operation of the Helley-Smith sampler, we did not observe disturbance of the bed during placement that would suggest "scooping" of the bed material by the sampler. However, we did observe that placement of the Helley-Smith sampler behind larger rocks or rock obstructions occasionally induced fine sediment movement into the nozzle from beneath the sampler when the sampler nozzle was not flush with the bed.

INTRODUCTION

Traditional methods for collecting bedload sediment with instruments such as the Helley-Smith bedload sampler (Helly and Smith, 1971) and analyzing the samples are labor intensive and therefore, can be quite expensive. Additionally, the quality of the bedload dataset collected using traditional methods may be of concern. Questions may arise about the consistency of a record due to variation in a field technician's technique, the location of the sampling cross-section, and placement of the sampler on the streambed. For example, it is difficult for the operator to determine whether the sampler is flush with the streambed, if the nozzle of the sampler is sitting behind an obstruction or whether instrument placement somehow disturbs the bed causing a pulse of sediment to enter the sampler.

Recently a number of inexpensive compact underwater video cameras have become available on the consumer market. These cameras allow the user to make underwater observations and capture video footage with a standard camcorder or video recorder. Ideally, an underwater video camera could be used to observe sediment moving along the streambed or the interaction between a sampler and bed materials. Since the cost of videotape is relatively low, capturing lengthy film segments is not a limitation. The ultimate challenge, however, is to determine whether the information obtained by these means can be quantified.

A number of studies used video imaging to track particle movement and interactions between particles in laboratory flumes (e.g. Brasington et al., 2000; Papanicolaou et al., 1999). Drake et al. (1988) employed a motion picture camera to view bedload movement and interaction in a natural stream channel. To our knowledge, there is no published work where a digital video camera was used in a natural stream setting to observe bedload sediment movement, interaction of bed particles or the interaction of a sampling instrument with the streambed.

OBJECTIVES

Our goal was to determine whether an underwater video camera would be a useful tool for observing bedload movement at our study sites, which are typically in steep, headwaters gravel and cobble bed streams. There are a number of concerns regarding the use of an underwater video camera system and its application to sediment transport field studies. In this paper we address: (1) whether there is sufficient visibility to record video under turbid and turbulent flow conditions, (2) whether the underwater camera has sufficient resolution to pick up the movement of individual grains, and (3) if the camera is rugged enough for typical field application. Our primary objective was to determine whether there is the potential to make quantitative measurement of sediment transport using underwater video imaging including: (1) identification and measurement of individual particles, and (2) trajectory and velocity of individual particles. Our secondary objective was to observe the operation of a Helley-Smith sampler to determine: (1) whether the sampler disturbs the bed when placed on the channel surface, (2) whether flow conditions exist near the sampler nozzle that affect sediment pathways, and (3) whether the sampler appears to pick up particles other than those being moved by natural flow conditions.

STUDY SITES

We chose 4 existing study sites at Fraser Experimental Forest (FEF) in Colorado and one site at Halfmoon Creek near Leadville, Colorado to observe bedload transport with the underwater video camera. There are up to 5 years of bedload data from each of these sites collected during periods of snowmelt runoff and covering a wide range of flows. Three of the sites are located on the main stem of St. Louis Creek; two of these are upstream from a trans-basin diversion and the other downstream from the diversion (Ryan and Troendle, 1996). The other site at the Fraser Experimental Forest is located at the abandoned weir on East St. Louis Creek where sediment was observed moving across a concrete pad. The Halfmoon site is located near the USGS gage south of Leadville, Colorado. We added the Halfmoon site later when it became apparent that runoff would be relatively low at the sites on FEF.

EQUIPMENT AND METHODS

We used the Seaviewer™ underwater video camera for this study though other manufacturers make a similar product. According to the manufacturer, the black and white version of the submersible camera is better under low light or murky conditions than their color counterparts. The Seaviewer™ camera consists of a single 1/3 inch charged coupling device (CCD) mounted in a compact plastic housing. The camera attaches to a long pole and is suspended from the stream bank or a bridge. To record video footage, the camera was connected to a camcorder with video-in capability. We used a consumer grade Sony Digital 8™ camcorder to acquire high quality images in digital format. The digital format facilitates image editing and processing using a desktop computer. The Seaviewer™ camera is equipped with infrared emitters allowing it to be used in complete darkness.

Since this was our first experience with an underwater camera, we were primarily interested in seeing what could be observed with regard to the behavior of moving bedload sediment. We chose to observe sediment as it moved laterally across the field of view, as the camera was pointed perpendicular to the direction of flow. This allowed us to watch particles move from upstream to downstream, and also allowed us to watch the open end of the Helley-Smith sampler as bedload approached the nozzle. Bedload samples collected with the Helley-Smith sampler were analyzed in the lab using standard sieve analysis (Griffiths, 1967). Suspended sediment samples were collected to quantify visibility during filming. The suspended sediment samples were filtered using standard laboratory analysis (Griffiths, 1967).

RESULTS

The snow pack for the year 2000 was lower than average in Colorado as were runoff levels. The main stem of St. Louis Creek at Fraser Experimental Forest briefly reached bankfull discharge on May 31 and flow levels declined quickly thereafter. East St. Louis Creek peaked at approximately the same time and high flows were sustained a bit longer. Our video taping occurred during this period of high flow. Sand and fine to medium gravel were the primary constituents of bedload at the St. Louis Creek sites. East Fork St. Louis Creek was quite active with particles 32mm and larger observed moving across the concrete pad. Halfmoon Creek approached but did not reach bankfull discharge prior to our visit. A second smaller peak occurred a few days later while we were present. We were able to view larger particles in motion at Halfmoon Creek due to low embeddedness of grains at the channel surface.

General Observations: Although we did not exceed a visibility threshold, it was apparent that during high flows at East St. Louis Creek we were approaching conditions where the video image would have been significantly degraded due to the relatively high load carried in suspension. The highest measured suspended sediment concentration was 43.7 mg/l at this site. Under these conditions, visibility was limited to approximately 3 feet. Larger particles could be seen, but smaller sediment that was the same brightness value as the background signal was difficult to differentiate. We estimate that roughly double this suspended sediment concentration, or about 100 mg/l, would have to be reached in order for visibility to be reduced to a point where larger particles would begin to be difficult to distinguish. However, entrained air bubbles seemed to be a greater impediment to viewing at the East St. Louis Creek site. As flows increased at East St. Louis Creek the image quality declined rapidly and it became difficult to distinguish air bubbles from moving grains.

Light Sensitivity: The camera performed well under very low light conditions due to its 0.3-lux sensitivity. At Halfmoon Creek we were able to see quite well as light levels declined to near total darkness. Since the black and white camera is sensitive to infrared light and equipped with infrared emitters, we attempted to use the camera under complete darkness. We conclude that the underwater video camera alone would not be suitable for viewing sediment transport at night. With the addition of supplemental infrared emitters, bedload may be viewable in complete darkness. Under direct sunlight conditions, when the water is relatively clear, visibility can be poor due to reflections from passing waves on the water surface. A possible solution to this problem would be to shade the portion of stream being studied.

Sediment Movement: Our initial observations at the East St. Louis Creek weir showed that we could easily see sediment moving from the streambed onto the concrete ramp where each particle was distinguishable. Gravel sized particles were much easier to see than smaller ones. Viewing transport of the smaller size classes was difficult because the particles accelerate as they reach the weir. The smaller particles could not be tracked because of the relatively slow 30 frames per second capture rate of the video camera.

East St. Louis Creek and Halfmoon Creek were the only sites where we observed coarse gravel movement. In a few instances, we observed the accumulation of an assemblage of particles that would persist a short time and then be disassembled. Sequentially, an initial particle became lodged, then other particles in transit would catch on the original particle. As the number of particles increased the entire structure became increasingly unstable and the initial particles began to vibrate. A short time later, particles were plucked away until all were removed, returning the streambed close to its original configuration.

At Halfmoon Creek we observed slurries of sand and pea gravel moving along the bed of the stream. Saltating particles in the coarse sand to fine gravel size class were typically moving too quickly to distinguish them when observing the video frame by frame. These smaller particles, however, were easily seen while the video was moving at a normal or slow motion speed. Larger particles in the medium to coarse gravel size class were moving slower and were easily viewed frame by frame.

Occasional sweeps were observed that would briefly entrain small to medium sized gravel. In some other cases a larger particle would turn over and come to rest or the particle would continue movement out of the view frame. For example, at Halfmoon Creek we observed a relatively large particle (b-axis = 46mm) move into the frame and come to rest behind a similar sized stationary particle (figure 1a). This particle adjusted its orientation slightly during the next 17 seconds. The particle then rolled over and came to rest downstream against a partially buried large cobble (figure 1b). The particle adjusted its position slightly during the next 7 minutes and 19 seconds as smaller particles filled in and subsequently scoured away both on top and beneath. Just before the particle moved out of the view frame, there was a sweep of sediment followed by the particle being struck by another particle (b-axis = 26mm) that initiated its movement out of the view frame (figure 1c).

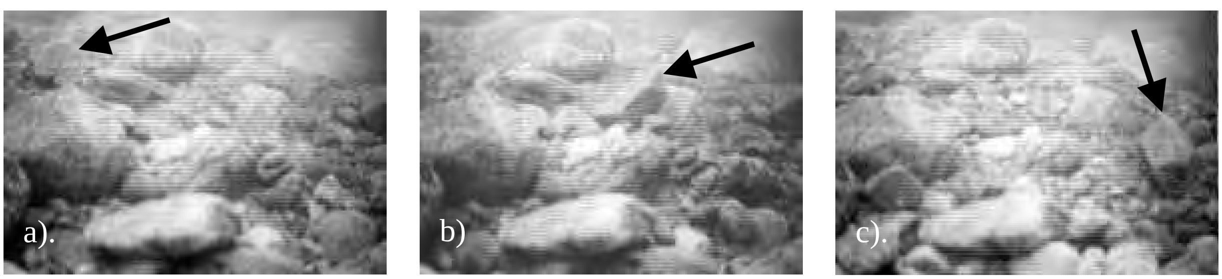

Figure 1. Track of a single particle at Halfmoon Creek. a). the particle moves into view and comes to rest, b). after 17 seconds the particle moves 23 cm and comes to rest again c). after being stationary for over 7 minutes, the particle moves out of the view. The video image is much clearer than these reproductions.

During periods of low flow, our video observations show that most bedload moves as swirling finer grained patches associated with flow obstructions. Although the smaller particles are difficult to see, they appear to be liberated from the swirling cloud and move to the next patch where they are caught up for an indeterminate period of time.

Helley-Smith Sampler Performance: We were able to identify individual particles moving into a bedload sampler by comparing the video image with the sediment trapped by the sampler. By knowing the vertical dimensions of the sampler and making measurements on the monitor, we were able to scale the size of particles against that of the sampler to determine their actual size. The size of an individual particle, along with its general shape and brightness value, aided identification from the sample.

We did not observe any disturbance of the channel surface by the mouth of the sampler during placement that might be considered “scooping”. Care was taken to ensure the mouth of the sampler was gently rotated into position. On rare occasion, the sampler appeared to disturb particles when placed behind rocks or on top of a loose patch of sediment, especially if the sampler was slightly elevated and not in good contact with the bed. Under these conditions, a small vortex is created beneath the sampler that causes the sediment that was previously immobile to be caught in the turbulence and taken into the sampler. This disturbance and subsequent movement of sediment into the sampler seemed to be more pronounced during periods of low-flow when there was generally not enough energy to move the particles under ambient conditions. In most cases, the pulse of sediment lasted only a few seconds after the initial disturbance. Given this observation, a short sample interval, such as 30 seconds, would increase the possibility that a significant percentage of the sample is in error. This suggests that the sampler might overestimate sediment transport in the finer size classes during low-flow under these specific conditions. As the sample interval lengthens, the percentage of sediment from the disturbance would decrease in relation to the total sample. During higher flows, the finer particles are already in motion and don't seem to be affected by sampler placement in this manner.

CONCLUSIONS

The underwater video camera allowed us to successfully view bedload sediment moving along the streambed. Although we did not reach a visibility limit, it was apparent that there was disintegration in the quality of the video when more material was in suspension. Therefore, video imaging would not be feasible in streams with very high concentrations of suspended sediment. Nonetheless, the video camera is particularly well suited to mountain streams with relatively low suspended sediment loads. Additionally, the underwater video would be inappropriate for use in step-pool systems where there is a considerable amount of entrained air bubbles. The camera can be used to directly measure particle sizes with a b-axis greater than about 15mm. The camera would be especially suitable for estimating the maximum particle size moving and its velocity.

The video camera records at a rate of 30 frames per second. This rate is somewhat slow for stopping the motion of the smaller, fast moving of particles. Our ability to observe sediment movement would generally benefit from a camera with roughly twice the capture rate or about 60 frames per second. In addition, we would benefit from a camera with better resolution, at least twice the numbers of lines per inch than the current products provide.

The Helley-Smith sampler appeared to work well under the conditions we encountered in the field. Careful placement of the sampler and longer sampling intervals are important for reducing error associated with collecting sand size particles during low-flow conditions.

In the future we plan to establish a visibility limit for using the underwater camera. We would like to observe sediment moving with the camera pointed directly downward from just below the water surface toward the streambed. We also plan to use several cameras in a series to determine transport patterns over an extended time period at a stream cross-section. In our future efforts, we will be able to improve the image quality by improving the stability of the camera lens when submerged. Continued experimentation will give us the opportunity to evaluate the camera under conditions of higher flow and sediment discharge.

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Abstract for Poster Presentation

RESTORATION OF TROUT CREEK, LAKE TAHOE, NEVADA

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Trout Creek, South Lake Tahoe, contributes 35.6 cfs in an average water year and is the fourth largest tributary to Lake Tahoe. Currently Trout Creek is a highly incised channel that runs along the side of a meadow. It is a major contributor of sediment to the lake. The City of South Lake is seeking to improve the natural function of the channel by reconstructing 9,000 channel feet. Willow root wads and stacked layers of sod are used along the outer banks of the new channel to reduce bank erosion. Ideally, creating a meandering stream will increase overbank flow and deposit suspended sediment and nutrients into the floodplain more frequently.

Trout Creek will be rechanneled in 2001 to meander through a wet meadow. Restoring the channel configuration and reconnecting the channel to its floodplain are necessities to the restoration of a properly functioning meadow. Restoration goals, in order of importance are to reduce sediment and nutrient yield to Lake Tahoe, improve riparian and meadow vegetation and finally to improve fish and wildlife habitat and population. The Desert Research Institute is working with the City of South Lake Tahoe to conduct a two-year waterquality monitoring plan evaluating the effectiveness of restoration of Trout Creek. Water quality data is being ascertained one year prior to rechannelization to observe background levels of constituents and one year after rechannelization to monitor changes in water quality, particularly, any changes in sediment loading to Lake Tahoe.

The research aims of the project seek to improve future monitoring capabilities by designing a model to correlate suspended sediment and turbidity and perhaps turbidity to nutrient levels. This would reduce future costs imposed by the physical collection of samples and the laboratory costs of analyzing for total suspended solids. Laboratory turbidity analysis of aliquots collected by the autosampler and by field personnel are compared with in situ measurements collected by the datalogger. Recent studies have demonstrated through statistical analysis of similarly paired data that a correlation does indeed exist. Our studies will further analyze the effects of sediment composition and dissolved solids on turbidity readings to identify geologic and anthropogenic catalysts to increased turbidity levels.

Photopoints, aerial photos, groundwater evaluations, topographic surveys of longitudinal profiles and cross-sections, bankfull discharge evaluations and floodplain soils analysis are being utilized to assess the geomorphology of restoration. Three dataloggers equipped with pressure transducers, nephelometric turbidimeters, water conductivity and temperature probes, and vacuum pump autosamplers collect in situ stream data. Daily, monthly and storm grab samples are analyzed for the following geochemoical constituents: total Kjeldahl nitrogen (TKN), Nitrate ($N0_3$), Nitrite ($N0_2$), Total Phosphorous (TP), Orthophosphate (OP), Total Suspended Solids (TSS), and Turbidity (Tu).

GRENADA RESERVOIR, MISSISSIPPI: FLOOD CONTROL, SEDIMENT, AND RESERVOIR DYNAMICS

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Abstract: Grenada Reservoir, created by completion of Grenada Dam in January 1954, was constructed as part of a comprehensive plan for flood control in the Yazoo River Basin in northwestern Mississippi. Two rivers, the Yalobusha and Skuna, contribute inflow to the reservoir, forming a distinctive Y-shape within the topography of the flood pool. Total watershed drainage area for the reservoir is approximately 3,419 square kilometers (1,320 square miles). Reservoir life expectancy was originally estimated at 25 years because of the high erosion rates of the region. However, the lake continues to function with only slightly reduced storage capacity. Reservoir sediment accumulation rates and contaminant concentrations were sampled in 1998 and 1999. Sediment accumulation within the permanent pool adjacent to the dam was less than 1cm/yr except for a depositional area near tributary inflow that accumulated sediment at about 5 cm/yr. The central area of the permanent pool has experienced sediment accumulation rates averaging less than 1.5 cm/yr. Sites within the two reservoir arms fed by the two river inflows showed little or no sedimentation. Sedimentation rates further upstream in these two inflow areas were also generally low. Sedimentation rates within Grenada Reservoir were higher until the mid 1960's & early 70's but were considerably lower thereafter. These lower sedimentation rates paralleled land use changes and followed discontinuance of major upstream channel alterations for flood control. In spite of long-term historical use of residual pesticides in the watershed and widespread use of currently applied agricultural compounds, concentrations in stream or lake sediments and overlying water were generally low or not detectable. Conversely, several metals (arsenic, lead, copper, iron, aluminum and zinc) were abundant in stream and lake sediments.

INTRODUCTION

Flood Control Reservoirs: With nearly 80,000 substantial reservoirs constructed within the continental United States, concerns about reservoir water and sediment quality are increasingly common as many of these reservoirs reach the end of their life-expectancy and are considered for de-commissioning or over-haul. During the 20th century, rapid increases in U.S. population, economy and technology spurred water control projects throughout the nation. Over half of existing U.S. dams were constructed during the period from 1945 to 1975, and the average age of U.S. reservoirs is 40 years. This suggests the need for greater dam maintenance and/or major rehabilitation (National Performance of Dams Program [NPDP], 2000). NPDP (2000) also estimated that dam safety costs alone over the next 20 years could range from $750 million to $1.5 billion due to loss of capacity from sedimentation. Mitigation of environmental and potential human health impacts from reservoir sediments and waters could potentially result in exponential increases above that amount. A far more comprehensive knowledge of the quantity and quality of sediments within reservoirs is needed to better address future management decisions. In this paper, we describe a study of one large reservoir, addressing questions of sediment quantity and quality within the lake, and the impacts on reservoir parameters from upstream watershed processes and modifications.

Grenada Lake Watershed and Reservoir: The U.S. Army Corps of Engineers (COE) completed Grenada Reservoir, located in Grenada County, MS, in 1954. It is one of 555 reservoirs operated by the COE out of approximately 2000 reservoirs controlled by the U.S. federal government (National Inventory of Dams - NID, 2000). Built primarily for flood control, the lake also serves for recreational activities, including swimming, fishing, and boating. It is one of over 3,300 reservoirs within the State of Mississippi referenced in the NID (2000). Maximum storage capacity of Grenada Reservoir is approximately 3.33 trillion cubic meters (2.7 million acre-feet), about one tenth the capacity of the largest U.S. reservoir, Lake Mead, Nevada. Water level in Grenada Reservoir is controlled by outlet gates and normal elevation (National Geodetic Vertical Datum – NGVD) ranges from 59 m (193 ft) NGVD (40 km2 or 9,800 acres of water) to a maximum flood control elevation of 70 m (231 ft) NGVD (261 km2 or 64,600 acres of water), but is held at a recreational pool level of 65 m (215 ft) NGVD (145 km2 or 35,820 acres of water) during the summer months. The reservoir's flood control purpose requires a fall season draw-down so that it will have maximum capacity for winter/spring rains (annual precipitation may exceed 140 cm).

Two rivers provide inflow into the reservoir, the Yalobusha to the south, and the Skuna to the north, creating a distinctive Y-shaped reservoir with two large lateral arms to the east and the main body westward. Flow within the watershed is from east to west, with controlled outflow from the reservoir into the Yalobusha River channel. Flow ultimately joins the Mississippi River along the western border of Mississippi via the Yazoo River that drains most of the northwestern region of the State. The contributing watersheds associated with the two river drainages entering the reservoir differ in that the Yalobusha River watershed is an area of intensive agriculture, including massive production of sweet potatoes, among other crops centered around the towns of Calhoun City and Vardaman, while the Skuna River watershed is currently less agricultural and more silvicultural.

The entire Grenada Reservoir watershed has been impacted by extensive drainage and channelization projects that began in the early 1900's. With the exception of approximately 14.5 kilometers (9 miles) in the lower Yalobusha River above Grenada Reservoir, all the river and major tributaries of the watershed have been channelized. Original channelization projects were conducted during the 1910's and 20's. Repeated additional works were conducted in the late 1930's to 1950's when the Yalobusha River and Topashaw Creek south of Calhoun City became plugged with debris and sediment. Late in the 1960's the U.S. Department of Agriculture Soil Conservation Service began another series of watershed modifications above the reservoir including extensive clearing and dredging of many channels, and installation of numerous gully erosion control structures. During this same time in the late 1960's, some dredging was also done in the upper reservoir, but the extent is unknown.

METHODS AND MATERIALS

Water and Sediment Quality and Cesium-Dating Samples and Analyses: Sample collection and storage were done according to suggested APHA (1992) methods. Samples were collected from overlying water and bottom sediment into properly cleaned and prepared glass sample containers. Analyses included concentration determinations for up to 8 metals and 46 pesticides or priority contaminants likely to occur, given the historical and current land use (Table 1). Samples from 25 stream/river locations within the Yalobusha River watershed were taken on about November 1, 1996, 1997 and 1999 from mid water-column and upper 10 cm of sediments. Additional water column samples were taken from 13 of these sites on five dates between July 1997 and June 2000. Sampling was not done in the Skuna River watershed due to mandated focus on the Yalobusha River system and logistic limitations.

Table 1. List of pesticides, contaminants and metals sought in water and sediment analyses.

ALACHLOR	CHLORPYRIFOS	METHYL PARATHION
ALDICARB	CYANAZINE	METOLACHLOR
ALDRIN	CYFLUTHRIN	METRIBUZIN
AROCLOR 1016	DDD	MIREX
AROCLOR 1221	DDE	NORFLURAZON
AROCLOR 1232	DDT	PENDIMETHALIN
AROCLOR 1242	DELTAMETHRIN	TEFLUTHRIN
AROCLOR 1248	DIELDRIN	TOXAPHENE
AROCLOR 1254	ENDOSULFAN I	TRALOMETHRIN
AROCLOR 1260	ENDOSULFAN II	TRIFLURALIN
ATRAZINE	ENDOSULFAN SULFATE	ARSENIC
BHC-ALPHA	ENDRIN	MERCURY
BHC-BETA	ENDRIN ALDEHYDE	LEAD
BHC-DELTA	FLUOMETURON	COPPER
BHC-GAMMA	HEPTACHLOR	IRON
BIFENTHRIN	HEPTACHLOR EPOXIDE	CHROMIUM
CHLORDANE	lambda-CYHALOTHRIN	ALUMINUM
CHLORFENAPYR	METHOXYCHLOR	ZINC

Samples from within Grenada Reservoir were taken at 9 locations. At each reservoir sampling site, sediment cores were taken to greatest depth possible with manual coring equipment and procedures from an anchored boat. Ten centimeter diameter sediment cores were driven, lifted into a clean semi-tubular ruled trough, and divided into incremental 10-cm sections by depth from sediment surface for metals, pesticides, contaminants and cesium-dating analyses. A minimum of 1 kg of sediment from each 10-cm depth increment was acquired for cesium dating. Concomitant with sediment sampling in the reservoir, water samples from mid water-column were collected for metals, pesticides and contaminants analyses.

Analyses for contaminants were conducted in part at the USDA-ARS National Sedimentation Laboratory using gas chromatographic methods (Bennett et al., 2000). Other analyses, including all metals, were done at the University of Louisiana Monroe Soil-Plant Analysis Laboratory using ASTM and USEPA approved methods.

RESULTS

Water Quality: Analysis of water collected from stream sites in the upper Yalobusha River watershed showed only 9.5% (253 "hits" out of 2648 possible) detection of pesticidal compounds in samples. The only non-metal compound found in average concentration greater than one part per billion (ppb) in watershed water samples was atrazine due to high level detections from storm-flow sample collections. Highest mean concentrations for non-metal compounds in the Yalobusha River watershed water samples were atrazine (51.75 ppb), metolachlor (0.169 ppb), tralomethrin (0.079 ppb), alachlor (0.06 ppb) and cyfluthrin (0.059 ppb) with all other detections well below 0.1 ppb. Lowest mean concentrations of metals observed from water samples within the Yalobusha River watershed were for mercury (0.005 ppb), copper (2.54 ppb), chromium (3.50 ppb), arsenic (3.51 ppb), lead (16.74 ppb), and zinc (56.8 ppb), and highest concentrations observed were for aluminum (3847 ppb) and iron (3999 ppb).

Within Grenada Reservoir, mid-column water sample analyses revealed only 11.31% of the possible non-metal contaminant detections. Again, the highest observed mean concentration of non-metal compounds was observed for atrazine (0.4 ppb). Cyanazine (0.21 ppb) and chlorfenapyr (0.12 ppb) were the only other compounds observed with mean concentration above 0.1 ppb. Mid-column reservoir water samples never revealed presence of mercury. Chromium (3.14 ppb) and arsenic (4.13 ppb) mean concentrations were similar to watershed levels, while lead (8.19 ppb) and zinc (21.86 ppb) were less than half of contributing watershed stream mean concentrations. Copper concentration in water within the reservoir, however, was nearly an order of magnitude greater (20 ppb) than in the watershed. Aluminum (2260 ppb) and iron (1791 ppb) still had the highest observed concentration of all measured metals but were approximately half of levels observed in the upper watershed.

Sediment Quality: Analysis for non-metal contaminants within the upper Yalobusha River watershed revealed only 12.59% of possible detections (N=1509) in sediments. While this small percentage of detections was observed, seven compounds were found to have mean concentrations greater than 1 ppb. Aldrin had a mean observed concentration of 22.69 ppb, but this was attributable to only 3 detections at high levels. DDT metabolites DDE (14.43 ppb) and DDD (4.73 ppb) were also present in elevated levels at one or a few collection sites; however, the parent compound, DDT, was not observed. Dieldrin (2.59 ppb), endosulfan II (1.94 ppb) delta-BHC (1.58 ppb), and fluometuron (1.38 ppb) all had mean observed concentrations greater than 1 ppb, and twenty-one other non-metal contaminants were detected at lower levels. Overall mean concentration of pesticides detected in watershed sediments was similar to that found for upper watershed water samples. Mean concentrations of metals observed in upper watershed sediments ranged from lowest for mercury (27 ppb), arsenic (3054 ppb), chromium (5725 ppb), copper (12091 ppb), zinc (14857 ppb), and lead (27853 ppb), to aluminum (3.06×10^6 ppb) and iron (4.99×10^6 ppb).

Reservoir sediments had the highest overall mean pesticide concentrations of watershed components tested. Within Grenada Reservoir, atrazine was found in greatest observed levels, with a mean concentration of 322 ppb. Both alachlor (157 ppb) and metolachlor (127 ppb) were also observed at high mean concentrations; however, alachlor was widely distributed within the lake while metolachlor was detected at only two sites. Methyl parathion (55 ppb) and trifluralin (27 ppb) were widely distributed among sampling sites. Chlorpyrifos (12.53 ppb) was observed only at 2 sites, while DDT (12.2 ppb) was observed throughout the reservoir. Three other pesticides had observable mean concentrations greater than 1 ppb in reservoir sediments; heptachlor (2.53 ppb), endrin aldehyde (1.75 ppb) and cyanazine (1.52 ppb), and eight other compounds were detected. Mean concentrations of arsenic (2792 ppb), copper (12499 ppb) and lead (24852 ppb) observed in reservoir sediments were comparable to upper watershed sediment concentrations. Mean mercury (69 ppb) and chromium (13999 ppb) concentrations in reservoir sediments were slightly over twice that observed for sediments in the upper watershed. Zinc (59461 ppb) and aluminum (12.2×10^6 ppb) concentrations were found at about four times above the mean level observed in the upper watershed, and mean reservoir sediment concentration of iron (18.5×10^6 ppb) was about 3.5 times higher than observed in upper watershed samples.

Sedimentation Rates: Sediment accumulation within the permanent pool adjacent to the dam was less than 1 cm/yr except for a depositional area near tributary inflow that accumulated sediment at about 5 cm/yr. The central area of the permanent pool closer to inflow experienced sediment accumulation rates that averaged less than 1.5 cm/yr. Sites proximal to the main reservoir body but within the two reservoir arms fed by the two river inflows showed practically no sedimentation, probably due to scouring action. Lake water level management practices result in summer and fall drawdown. Subsequent seasonal inflow is constricted in these areas and may also result in underflow currents. Observed sedimentation rates further upstream in these two inflow areas were also generally low. Overall, sedimentation rates within Grenada Reservoir were higher until the mid 1960's & early 70's but were considerably lower thereafter. These lower sedimentation rates paralleled land use changes that reduced row-crop agricultural area and increased soil conservation measures. Lower sediment accumulation also followed discontinuation of major upstream channel alterations aimed at flood control.

DISCUSSION

Most pesticides were detected seasonally at low concentrations in contributing streams. Atrazine was the only current use pesticide found in significant concentrations in streams draining into Grenada Reservoir. In lake water it was also detected, but at less than two orders of magnitude below watershed level. However, concentrations were higher in lake sediments. Atrazine has been previously shown to be a widely detected contaminant of streams and rivers in the Midwestern U.S., particularly following high-flow runoff events (Council on Environmental Quality, 1993) and, as shown by our results, can accumulate in reservoir sediments. Although mean atrazine concentration was highest in reservoir surface sediments, detection rate was only 57%. Naturally occurring metals were found in high concentrations, particularly aluminum and iron. Residual contaminants such as DDT were detected in low concentrations, particularly in lake sediments. Our observations corresponded to national findings. While nation-wide advisories against fish consumption due to mercury and PCB more than doubled for the U.S. from 1993 to 1998, cases due to dioxin and chlordane have remained level and those due to DDT have declined as environmental levels of past-use pesticides drop (U.S. EPA, 1999). Watershed use has had a measurable effect on reservoir sediment accumulation. In spite of continuing erosion problems in the watershed, sediment accumulation does not present immediate threats to reservoir storage. Accumulating sediments are not presently creating significant water quality difficulties.

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CONSTRUCTION OF AN ENVIRONMENTALLY SENSITIVE CHANNEL STABILIZATION, MARRE CANYON CREEK, SANTA BARBARA COUNTY, CALIFORNIA

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Abstract: Over years of ranching and farming, Marre Canyon Creek had degraded to a narrow channel, 30 feet deep, with unstable vertical banks, and limited vegetation. Native mature oak and pine trees had fallen off the banks, or were at risk from undermining and root exposure. Two miles of creek were stabilized through construction of low visibility chute grade stabilization structures, raising of the creek bed, and shaping banks. This created stable conditions for revegetation, habitat establishment, and minimal future maintenance. While the presence of high-valued vineyards adjacent to the creek limited opportunities for geomorphically-based channel restoration, the Marre Canyon Creek project is notable for its balance between creek preservation and intensive farming practices. Critical to the project construction was the communication between the owner, inspectors, and contractor for the purposes of preserving the natural creek meanders and the riparian tree cover.

INTRODUCTION

Marre Canyon Creek drains approximately 2000 acres to the Santa Ynez River and to the Pacific Ocean on the central coast of Santa Barbara County, California. This creek is typical of many in the region in that historical land use, including cattle grazing, has led to the creation of incised channels through flow concentration, down cutting, and head cutting. Channel depths of 30 feet are common. Stream meandering and bank sloughing increased the extent of the eroded channel, creating an impassable barrier for farming and ranching operations, and causing increasing economic and environmental damage downstream. Culverts at road crossings, each of which left a 10-15 foot deep scour hole below the outlets, temporarily limited headcut erosion. One of these culverts was blocked by debris and failed in the 1998 El Nino storm season. The resulting headcuts discharged quantities of sediment 2.5 miles downstream to close a county road and flood a thoroughbred horse ranch.

As part of a comprehensive vineyard development, the landowner requested that the stream restoration maintain the natural creek environment to the greatest extent possible. To overcome the creek degradation, four chute structures were installed, each raising the creek bottom an average of 14 feet. Bridge crossings were incorporated over the inlets of each of the four structures, greatly improving farming access throughout the vineyard. Extraordinary effort was made by the contractor and the inspectors to preserve the natural meanders of the creek, as well as the native valley oak and pine trees. The hydraulic configuration of the chutes is such that the structures in the creek are barely noticeable except for the crossings over the inlets. The creek channel stabilization cost approximately $1 million. The USDA-NRCS, and Cachuma Resource Conservation District staffs, Santa Maria, CA provided design and construction engineering.

SITE DESCRIPTION AND CHANNEL ALIGNMENT

Santa Barbara County, California has a Mediterranean type climate, with most precipitation occurring between November and March. Due to weather patterns and orographic effects of the mountainous terrain, Santa Barbara County is subject to some of the highest short duration rainfall intensities in California[1]. Young alluvial deposits exposed in the streambanks consist of stratified sands and gravels deposited during such short duration, high intensity rainfall events. Lenses of these permeable, cohesionless strata occur at varying depths across the width of the current and historic meander corridor. The meander pattern of Marre Canyon Creek has varied over time, which has left permeable, cohesionless strata at varying depths both on and off the existing channel alignment. This presented challenges for the channel stabilization in terms of preventing seepage or soil piping paths around the grade stabilization chute structures. Other than the permeable lenses, the predominant soil is mapped as Salinas silty clay loam (Unified classification CL)[2], which is well suited for structure embankments and stable creek banks.

Channel Alignment: With the exception of the four structure sites, the natural channel alignment of Marre Canyon Creek was preserved. A distance of approximately 150 feet upstream and downstream of each structure was realigned, as necessary, to ensure stable entry and exit of accelerated creek flow through the chutes. Without these alignments, bank erosion and scour holes could create a risk of structure failure, followed by catastrophic headcut erosion and downstream sedimentation. Based on an average of 400 feet of channel realignment for each of the four structures, approximately 18 percent of the channel was realigned. The project team recognized that creek realignment typically means straightening and reduction of the channel length. This has a direct effect of increasing the creek gradient, and increasing flow velocities. Through the design, and communication with the contractor during construction, creek realignment was kept to a minimum, despite the extra effort and smaller earthmoving equipment that was required in some locations. The minimal number of trees which had to be sacrificed for creek stability were analyzed individually, and marked in the field by the project inspectors.

Channel Cross Sections: The incised creek channel banks were nearly vertical and unstable in many locations, especially at short radius meander bends. Bank shaping to stable 2:1 (horizontal : vertical) slopes generated sufficient soil to raise the channel bottom to a stable grade between structures. Channel bank stability was enhanced both by the flatter side slopes, and the shallower bank height. Raising and widening the creek bed also reduced the flow velocity to within allowable limits for erosion. Regular field meetings were held between the contractor's earthwork foreman and the inspection team, to agree on the best approach for preserving riparian trees, at the same time as stabilizing channel banks. In critical locations, "sliver cuts" and "buttress fills" of channel banks were necessary. For the channel bank fills, it was sometimes necessary to overbuild the fill using stepped terraces for good soil compaction, followed by trimming back to the finished slope using a "slope board" on the dozer blade.

HYDRAULIC DESIGN

Stable Grade: Stable channel gradient determination is critical to the design of a grade stabilization and creek restoration project. Headcut erosion and flattening of the channel bottom gradient were the processes that led to the narrow, incised creek section with depths of 30 feet or more. To re-establish a stable cross section with non-erosive velocity under design flow conditions, it was necessary to restore a broad, shallow channel. The Project's design flow was based on a 4 percent event (25-year storm). A detailed hydrologic study was performed using USDA-NRCS methods, coupled with field calibration using known storm events and specific hydraulic structure capacity observations. Stable channel bottom grade determination was based on the allowable velocity approach described in NRCS Technical Release No. 25 [3]. Existing channel gradients were also significant factors in the selection. Design grade for the channel invert ranged from 1.8 to 1.9 percent. Although science-based, stable grade determination is still a best estimate. More conservative (flatter) slopes were used to determine the depth of the structure outlet cutoff wall. This provides an additional margin of safety to protect structure outlets in case grades are flatter than predicted.

Structure Hydraulic Design: Hydraulic sizing and proportioning of the rectangular chute grade stabilization structures was based on NRCS Engineering Handbook Section 14, Chute Spillways [4]. NRCS methods provide for a minimum of 20 percent reserve capacity within the structures. This is based on actual flow capacity, rather than a fixed height of freeboard for the structure walls. Water surface profiles were calculated for subcritical flow upstream and downstream of the structures, and supercritical flow within the chutes. The accelerated flow within the chutes resulted in a wall height of only 2'-9" in the sloping channel section. This aspect of the hydraulic proportioning is what prompted the landowner to comment that the structures are barely noticeable while passing along the top of the creek bank. The chute outlets have higher sidewalls to contain the hydraulic jump where the flow returns to the subcritical creek channel flow. Outlet sections were submerged 4 feet below the creek bottom to ensure that the turbulent flow stays within the structure limits and does not create a scour hole.

REVEGETATION AND HABITAT RESTORATION

Since an incised creek also functions as an open drain, the raised creek bed serves to elevate ground water elevations in adjacent fields. This will enhance the natural colonization of the riparian plants native to the area. The post-construction revegetation plan called for erosion control seeding and mulching. The seed mixture applied was 12 lbs/acre Blando Brome (Bromus mollis) and 8 lbs/acre Lana Vetch (Vicia dasycarpa). The Blando Brome is a common erosion control grass in the area since it is known to be a good producer of seed for subsequent years. The Lana Vetch is a legume, which fixes nitrogen that becomes available as a plant nutrient. Due to the uncertainty of rainfall patterns, the landowner provided hand-move surface sprinkler lines along both sides of the creek to germinate and sustain the seeded areas throughout the length of the restored creek channel. There was good germination and growth, due in part to the heavy straw mulching, and the supplemental irrigation. The prospect for subsequent regrowth of annual plants is good, since the seeded plants were sustained through maturity and seed production. Where supplemental irrigation is not available, a risk with seeding or hydro-seeding is that the plants germinate, but afterward die if rainfall is insufficient to sustain growth.

Prior to the grade stabilization-creek restoration project, channel banks were fairly devoid of vegetation due to the over-steepened unstable side slopes. The restored creek banks are stable, and capable of supporting diverse vegetation. Preservation of the riparian tree canopy provides shade, wildlife escape cover, and cooler water temperatures.

Woody riparian vegetation, such as willow tree cuttings, were not included in the revegetation. This was considered, but not included due to the adjacent vineyards along the valley floor. Pierce's disease (*Xylella fastidiosa*) is borne by an insect vector, the glassy winged sharpshooter (*Homalodisca coagulata*), which is attracted to and migrates via willows and other woody plants. Pierce's disease has recently devastated vineyards in southern California, and is a great concern for vineyardists on California's central coast.

LESSONS LEARNED FROM CONSTRUCTION

1. Project drawings and specifications should clearly convey the desired end result of the creek restoration. It may be difficult to depict in the drawings all aspects of channel grading (such as creek meander and tree preservation), but communication with the contractor during the bidding and construction phases can reinforce these objectives.
2. As with any construction contract, the methods of measurement and payment need to be known and agreed upon between the project engineer and contractor, e.g. categories of earthwork, and survey measurements needed for determining quantities.
3. Soil borings should extend to the full depth of any construction, e.g. to the base of the structure outlet cutoff wall. This would reveal not only the soil classifications and stratification, but also the presence of ground water or bedrock.
4. Supplemental irrigation can be vital in establishing and maintaining erosion control seeding and habitat restoration.

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USE OF USGS DISCHARGE MEASUREMENTS TO DETERMINE SCOUR AND FILL AT SELECTED STREAM SITES IN MISSISSIPPI

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Abstract The USGS actively measures stage and discharge at numerous stream sites in Mississippi and throughout the United States. Maximum depth from a discharge measurement can be used to compute minimum-bed elevation in order to obtain an understanding of the ranges of bed fluctuations (scour and fill) that have occurred at a site. Minimum-bed elevations were obtained from 2,965 discharge measurements obtained during 1938-94 at 22 selected stream sites in Mississippi. At each site, the lowest minimum-bed elevation was subtracted from the highest minimum-bed elevation to obtain total-scour depth at minimum-bed elevation. Total-scour depth from these measurements represents mostly general and constriction scour, and possibly include some pier scour, depending on the proximity of the soundings to bridge piers. The total-scour depth at minimum-bed elevation for sites with more than 20 discharge measurements ranged from 5.2 ft to 29.8 ft.

INTRODUCTION

Fluctuation of minimum-bed elevation or total-scour depth observed through time is a good indication of bed stability. Blodgett (1989) noted that total-scour depth at minimum-bed elevation (deepest scour) is important in bridge design because it is the worst-case scenario. If there is significant lateral movement of the channel, total-scour depths larger than those at minimum-bed elevation could actually occur through time at an overbank pier.

Measurements of water depth and velocity to determine discharge were obtained using standard streamflow-gaging procedures as described by Rantz and others (1982). During flooding conditions, depth, vertical position, and velocity were measured by suspending a 100-, 150-, or 200-pound Columbus-type sounding weight and a Price AA-type meter in the water. Maximum measured depth was subtracted from the stage to determine minimum-bed elevation for each discharge measurement.

SCOUR AND FILL DATA

Minimum-bed elevations were obtained from 2,965 discharge measurements obtained during 1938-94 at 22 selected stream sites in Mississippi. At each site, the lowest minimum-bed elevation was subtracted from the highest minimum-bed elevation to obtain total-scour depth at minimum-bed elevation. Total-scour depth from these measurements represents mostly general and constriction scour, and possibly include some pier scour, depending on the proximity of the soundings to bridge piers. The total-scour depth at minimum-bed elevation for sites with more than 20 discharge measurements ranged from 5.2 ft to 29.8 ft. The recurrence intervals of the measured discharges ranged from less than 2 to about 500 years. Wilson (1995) describes these data in more detail.

Data for Chunky River at U.S. Highway 80 near Chunky, Mississippi, are presented in this paper to illustrate a stable channel bed at a Mississippi stream site (fig. 1a). The piers at this site are near midbank of each bank and, therefore, do not significantly influence scour of the main channel. The streambed at this site consists of sand and some gravel overlying a resistant siltstone and sandstone of the Basic Shale member of the Tallahatta Formation (M.J. Wright, written commun., 1994). Minimum-bed elevations at this site were mostly between 268 and 269 ft and varied only 1 to 2 ft, except for the period of the 1950’s to the late 1970’s when there likely was infilling to the highest minimum-bed elevation of 272.7 ft (fig. 1a).

Two sites with the largest total-scour depths at minimum-bed elevation are shown in figs. 1b and 1c. The maximum recurrence interval of the measured discharges at these sites is only 15 years. Therefore, the total-scour depths during extreme flooding could be larger than the total-scour depths shown in this paper.

The 29.0 ft of total scour at minimum-bed elevation at Leaf River at U.S. Highway 11 at Hattiesburg, Mississippi, was unexpected because there had been no known scour problems at the site (fig. 1b). The site is on a streambed consisting of sand and gravel and is located downstream of the mouth of Bouie River. Gravel mining on Bouie River upstream of its mouth is contributing to the variations of minimum-bed elevation at this site.

The 29.8 ft of total scour at minimum-bed elevation at Homochitto River at State Highway 33 at Rosetta, Mississippi, was expected because the site has known scour problems (fig. 1c). The site is on a streambed consisting of sand, which degraded about 15 ft between 1941 and 1974 (Wilson, 1979). By plotting the annual minimum-stages through time, the bed at this site has fluctuated and lowered only about 1 ft between 1974 and 1994, and degradation appeared to have ceased. Widening is the dominant process occurring at this site. The channel at this site moved laterally about 790 ft northward between 1953 and 1990 (Turnipseed, 1994). As much as 49 ft of total scour, including lateral erosion, has occurred on the north overbank. As much as 25 ft of variation in minimum-bed elevation occurred in a given year in the 1950’s and 1960’s, but since the 1960’s, the fluctuation in minimum-bed elevation has decreased (fig. 1c). A 600-ft-long bridge was in place until 1974, when it collapsed. This bridge was replaced with a 1,500 ft-long bridge that was completed in 1978. The minimum-bed elevation fluctuated more at the 600-ft-long bridge probably because the channel was significantly narrower than it is today and the bridge consisted of shorter spans. The 600-ft-long bridge consisted of 60- and 80-ft-long spans, whereas, the 1,500-ft-long bridge consists of 250-ft-long spans. The shorter bridge spans allowed more debris piles and bridge piers to obstruct the approach flow. Available discharge measurements indicated significant overlapping of pier-scour holes at the 600-ft-long bridge.

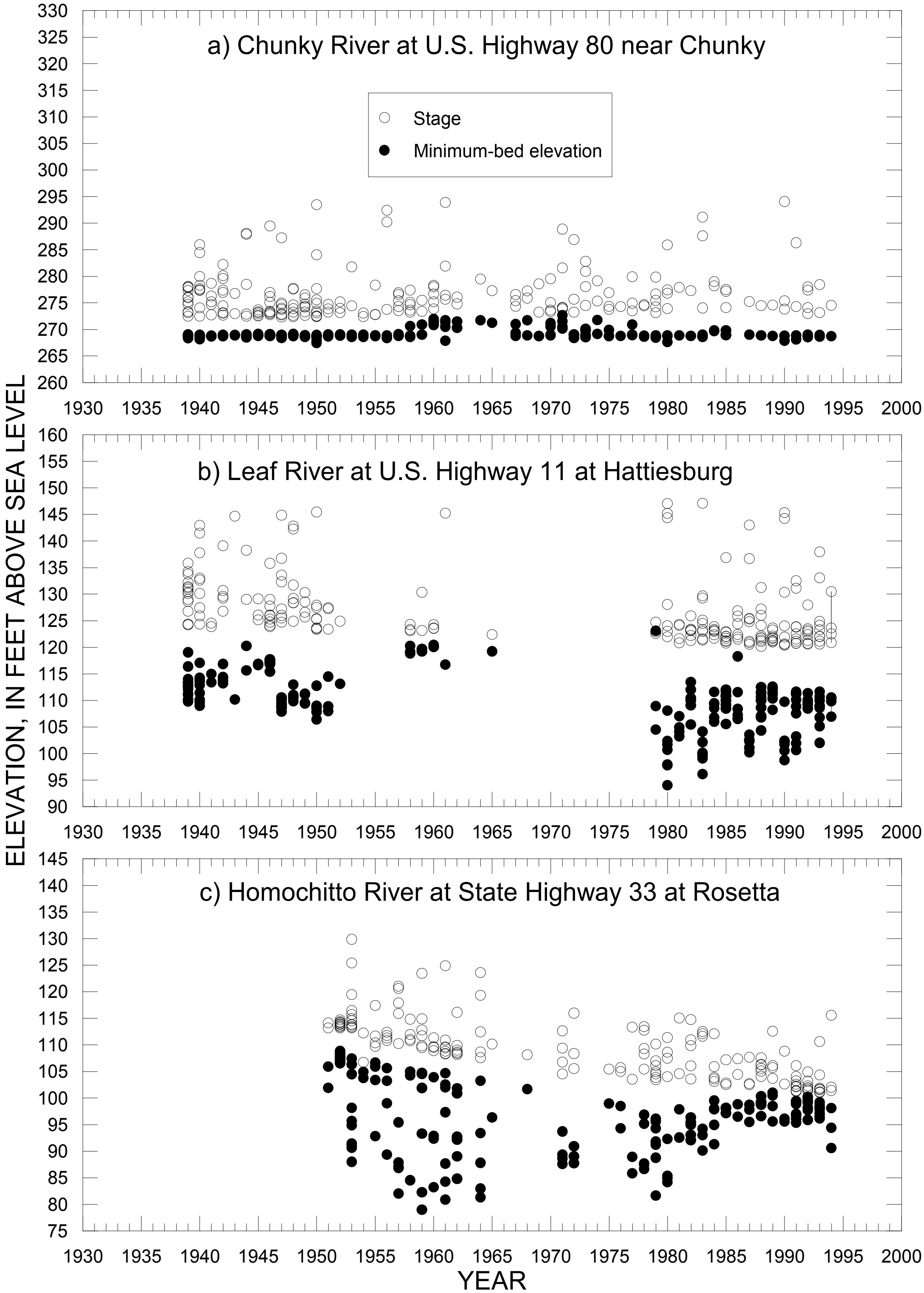

Figure 1. Relation of measured stage and minimum-bed elevation to time for three selected sites in Mississippi.

CONCLUSIONS

The USGS actively measures stage and discharge at numerous stream sites in Mississippi and throughout the United States. Maximum depth from a discharge measurement can be used to compute minimum-bed elevation in order to obtain an understanding of the ranges of bed fluctuations (scour and fill) that have occurred at a site. Total scour depths were determined by obtaining minimum-bed elevations from 2,965 discharge measurements. The total-scour depth at minimum-bed elevation for sites with more than 20 discharge measurements ranged from 5.2 to 29.8 ft.

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SEDIMENTATION PROBLEMS AND RIVER SEDIMENT MONITORING PROGRAMS IN NEPAL.

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Abstract

The prediction of sediment yield on Nepalese watersheds is rather a difficult task. Surface erosion is highly pronounced with high intensity monsoon rain. The river flows are laden with high concentration of sediment during rainy period. The erosion, transportation, and deposition process vary with topographical zone. The institutional development of hydrological and meteorological investigation began in 1961 as a joint venture between HMG/N and USAID. But, there are only some sediment gauging stations that are partially in operation at present. Due to increasing demand of river sediment data, it is felt necessary to upgrade the existing monitoring system. A Phase-wise approach could be recommended to upgrade the existing sediment monitoring network.

EROSION AND SEDIMENT YIELD

Erosion rates in Nepal:

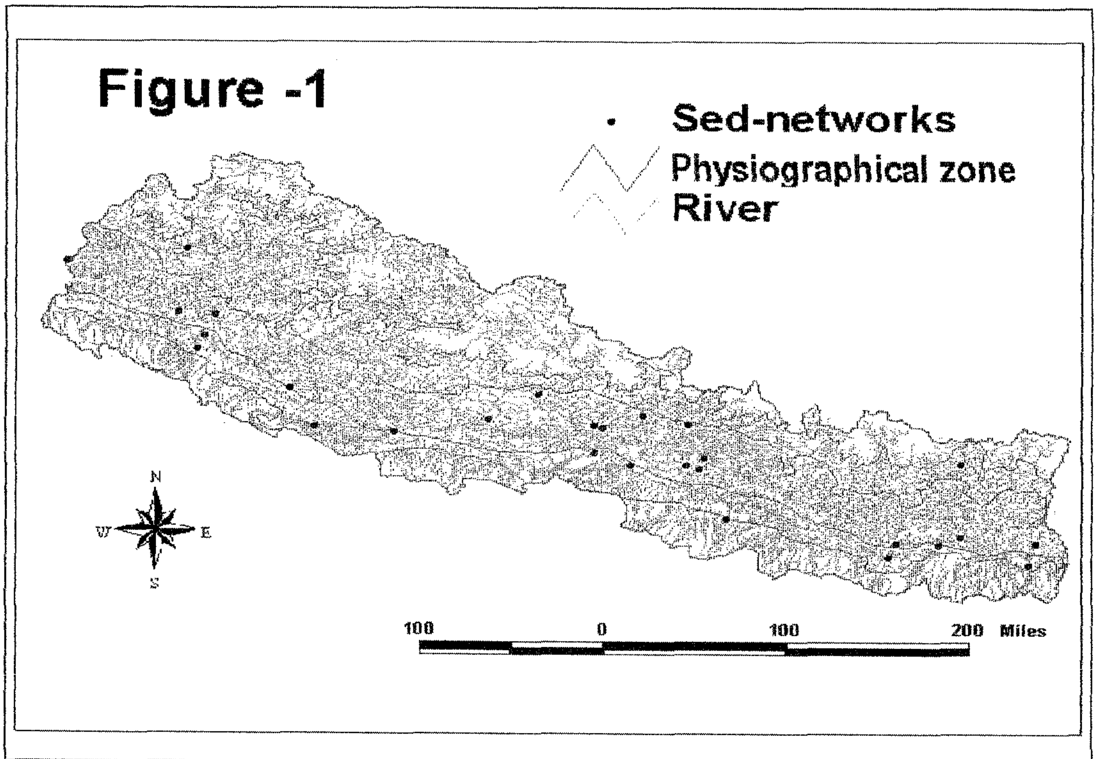
The latitudinal variation within a span of about 200 km ranges from about 70 meter above mean sea level at Jhapa district in the southeast Nepal to 8848 meter the top of Mount Everest in the north-east region. Mountains and hills occupy about 80 % of the total national land. The available reports on sediment transport study are mainly based on data collection for suspended sediment concentrations. Sediment data records are of the short duration, not representative, and not consistent with time and space. However, based on data collected by DHM and information available from different other sources, consultants have been analyzing data and tried to generalize the phenomena. Sediment transport during pre-monsoon period is higher than monsoon and post-monsoon period. Debris flows in gullies are significant carriers of sediments into rivers. The erosion, transportation, and depositional process vary with geo-morphological zone. The large river basins like Koshi, Karnali and Gandaki can not be regionalized as the individual unit because the rock hardness factor varies widely from high Himalayas to Siwaliks. Various researchers (Chapter,1976, Laban,1978, Mulder,1978, CWC,1981) have reviewed the status of erosion rate as given in Table – 1.

Table 1: Erosion Rates in Nepal :

Region	Land use/geological formation	Erosion rate tons/km^2/yr
Siwaliks	Eastern Nepal; Chatara Foothills of different land use, Sandstone, conglomerates	2,000 -20,000
Middle Mountains	Kathmandu Valley, Northern foothills of granites migmatites with week consolidation	2,700 - 57,000
Mahabharat Lek (high mountains)	Central Nepal, Metamorphic and Sedimentary rocks	3,000 - 42000

Table 2 : Sediment Yield

River system within watersheds	Sediment yields (tons/km^2/yr).
Rivers penetrating from Tibet region	500 - 1000
Rivers draining high Himalayas region	300 – 1000
Rivers draining middle mountains region	3000 - 8000
Rivers draining Siwaliks region	5000 -15000



PROBLEMS

Affected sectors :

Nepal is rich in hydropower generation which at present, is utilized only to a fraction of its potential. Next to the production of hydro-energy, other aspects of water resources utilization such as irrigation, water supply, flood protection and the ensuring of environmental standards with regard to the river landscape have to be considered for a sustainable resource management. Nepal poses a serious problem for sustainable development of water resources due the lack of reliable data on river sediment. Data on sediment transport neither as concentrations nor as transport rates are yet published.

Adverse effects that are seen due to lack of sufficient and reliable river sediment data. Some of the severely effected sectors due to unchecked and uncontrolled sediment transport as well as debris torrents are presented in Table 1.

Table -1

Causes/Effects	Affected area.in Nepal
Untimely silting of reservoirs	Kulekhani reservoir: a storage type
Excessive wear on turbine runners	Marshyangdi hydro project: a runoff type
Siltation of canals, river braidening	Irrigation canals and rivers in Tarai
Scouring of river beds and bank cutting	Bridges in KTM valley
High concentration of suspended load	Intake of Chitwan lift irrigation project
Blocking of river stretches	Occurred in South-central Nepal in1993
Uncontrolled changes of river courses	Occurred in South-central Nepal in1993
Destruction of weirs and dam components	Occurred in South-central Nepal in1993
Temporary rises of river bed	Washout of bridges and settlements in1993

Thus, it is highly recommended to upgrade the existing sediment monitoring networks. Large basins are to be divided into several relatively homogeneous units and additional gauging stations are to be established. It is also recommended to start bed load sediment data collection for selected river basins.

Challenges in sediment data collection:

At present, the sediment-measuring networks and monitoring program are not maintained due to various reasons like insufficient budget, staff retirements and lack of new-trained staff. Management too needs to be improved. In addition, the diagram below briefly describes the challenges in achieving goals.

Figure 2

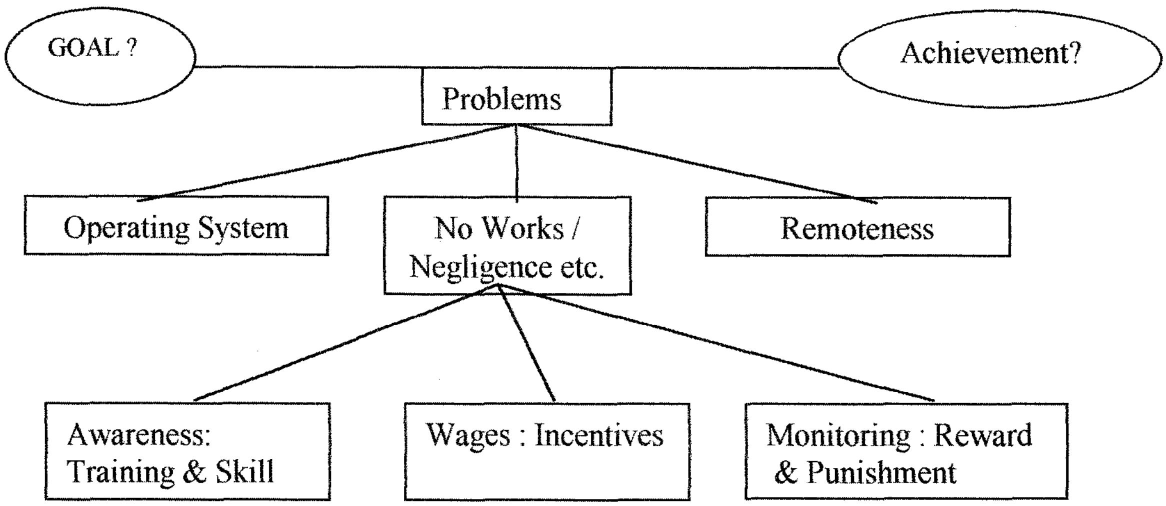


Table –2: Some of major pitfalls in the sediment study program

Administrative related factors	• No rules to upgrade senior technicians • Part time jobs to the local observers • Inadequate instruction and job description • No Check : No rerward and no punishment • Inadequate field visits • Poor field work management • Lack of staff coordination and inadequate interaction among staffs • Impractical salaries
Human resource	• Lack of qualified and trained staffs • Lack of hydrologist/ or sedimentolist • Lack of coordination and communication
Training and skill development	• Lack of training to observers and technicians in the field • Lack of awareness of the importance of data • Lack of seriousness, and reseponsibility taking • Lack of time schedule maintaining • Lack of uniform sharing of duties
Others	• Lack of monitoring on collection, processing and publication • Delay in transporting samples from site to the laboratory • Delay in sending the sampling bottles to the sites • Delay in analysing the samples in the laboratory • Insufficient and unscientific sampling during rainy period • Very low priority for sediment monitoring activities • Lack of accountability of the data users

MONITORING PROGRAM - A PROPOSED PROJECT SCHEME

Given the difficult institutional, logistic and budgetary situation and allowing for the growth of experience for a new sediment measuring network in Nepal, a phase-wise (Table-3) approach is planned for the implementation of the sediment measuring network. Experiences gained during different phases can be used to refine the efficiency of the measuring networks to ensure the reliable data collection and study.

Pilot Phase (6 months)

Installation of the first station should commence at the existing site of Khokana in Bagmati river, which is close to the Kathmandu central office. This station is planned to serve as the principal experimental station where new sampling techniques and observational routines will be tested. Site specific turbidity measurement as well as bed load sampling techniques will be tested. For a testing period during the pilot phase, methods that requires filtration in the laboratory or on site can be used in parallel to obtain a measure of reliability for on-site filtration methods. Practical training courses will be conducted for station observers and technicans. The trained persons shall be utilized as trainers. A hydrologist of DHM will be enrolled to a suitable university as on the job research.

An inter-departmental seminar/workshop on methodologies and outputs will be organized at the end of the pilot phase. User's need assessment will be carried out before prioritizing and finalizing the proposed sediment monitoring networks.

First Programme Phase (12 months)

Using the experiences from the pilot phase four additional monitoring stations will be established and operated in Bagmati river basin. The river sites for these five stations should be in line with basin development priorities and user's need. In this phase, station observers and the staffs of one basin office are to be trained.

Second programme phase (12 months)

The objective of this phase is to establish 10 additional monitoring stations for sediment measurements. The sites are again to be selected in accordance to the priorities. Building on the experiences gained from the pilot phase and the first phase, the programme and adjustments in the measuring plans, observational routines and on-site as well as laboratory processing will be made, In this phase, laboratory facilities and training is planned to be extended to the station observers and staff of three additional basin offices.

Third programme phase (12 months)

During this phase, 15 additional stations will be established and two basin offices will be equipped with laboratory facilities.Training will be given to field and laboratory staffs.

At the end of the project, the core sediment sampling network will be comprised of 30 sampling stations and 4 basin laboratories including the central laboratory in Kathmandu. DHM technical staffs working in the sediment division will be trained in subjects like data collection, processing and laboratory analysis. DHM will build up capacity in maintainance and repair of instruments/equipments by collaborative work with local Wokshop/repair industries.

In addition, on the job research work in the field of sediment and hydrology on Nepalase streams/rivers/watersheds will have been started and continued.

Table – 3 : Work Plan

Phase	Major Activities	Monitoring sites
Pilot	Techniques and equipment type selection : Sampling, analyzing and, processing. Training and seminar/workshop	One
I-Phase	Techniques adaption and application (tested in phase-I), data collection, processing. Data publication, training and workshop	Five
II-Phase	Technology Development : Bed load study, equipments, data collection, processing. Data publication, training and workshop.	Fiften
III-phase	Model development : Sediment yield study. Data collection, processing and publication, training, seminar/workshop	Thirty

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