Compendium of the Results of the 1996 STAR Water and Watershed Grants

Submitted to

U.S. Environmental Protection Agency
Environmental Science Center
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30 April 2003

FOREWORD

This report was prepared by Technology Planning and Management Corporation, for the U.S. Environmental Protection Agency, National Center for Environmental Research, Science to Achieve Results Program. TPMC prepared the report under the U.S Environmental Protection Agency National Geospatial Program and Mid-Atlantic Integrated Assessment (MAIA) Pilot Project on a contract with the U.S. Department of Commerce, Commerce Information Technology Solutions (COMMITS) Office Contract No. 50CMAA900065. The mention of trade names, commercial products, or organizations does not imply endorsement by the U.S. Government.

The preferred citation for this report is:

Walbeck, E.S., E.A. Merritt, J.F. Campbell, K. Stevens. 2002. Synthesis of the 1996 STAR Water and Watershed Grants. Prepared by Technology Planning and Management Corporation, Scituate, MA, for the U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Research, Science to Achieve Results Program.

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1. INTRODUCTION

1.1 Background

The Environmental Protection Agency (EPA) STAR (Science to Achieve Results) Grant program funds research in a wide variety of environmental science disciplines. The STAR Water and Watersheds program is unique in that it advocates interdisciplinary research. However, in order for the information gathered from this research to be useful to decision makers, stakeholders, and the science community, it is beneficial to summarize the results into comprehensive and easily accessible documents. In concordance with their commitment to communication, the National Center for Environmental Research (NCER) is supporting a set of documents that highlight research results and successes. The purpose of this project is to develop a compendium of the results of the 1996 STAR Water and Watershed Grants and produce a document that outlines the results, products produced, and user communities for each of the 1996 Water and Watershed grants.

Because this product will be used directly by EPA, and to avoid any bias associated with the research projects, an extramural contract was chosen as the appropriate vehicle to complete this task.

1.2 Summary

Ten 1996 Water and Watershed EPA STAR Grants were reviewed in detail to determine how results of this research can or is being used by both other researchers and decision-makers. Products useful to decision-makers resulting from the 10 grants include:

- Six models;
- Eight methods, strategies, processes, or tools
- Four charts, diagrams, or matrices;
- One course for environmental professionals;
- One field guide;
- One presentation for state and local agencies; and
- Results of three stakeholder surveys.

Additionally, three new methods for analyzing carbon cycling rates were developed for use in future research. Nine grants fell into two or three of the following categories/themes and one included four categories (See Appendix B):

- Wetlands,
- Restoration,
- Urban conditions,
- Agricultural conditions,
- Economics,
- Harmful Toxins,
- Politics and policies,
- Scientific Techniques,
- Microbial activity, and
- Multi-criteria studies.

A summary of each of the 10 grants, including results, products produced, user community, and themes, follows. The appendices include: 1) a summary table of each grant listing grant number, title, principal investigator, common themes, relevance, products, and successes/lessons learned (Appendix A); 2) a table showing which grants had which common themes (Appendix B); and 3) a very brief description of each grant by common theme (Appendix C).

2. SUCCESSES, RESULTS, AND FINDINGS

2.1 STAR Grant R824905

Large Scale Disturbances and Small Scale Responses

Principal Investigator: Dr. C. Andrew Cole, The Penn State Cooperative Wetlands Center

Successes/ Lessons Learned:

Created wetlands are rarely successful under any circumstances.

- *Surrounding landscape influences plant communities.*
- *Created wetlands did not meet standards of "good," natural wetlands.*
- *Biomass remained high in created wetlands, but soil organic matter did not increase, as it should, over time.*
- *There is high mineral accretion in floodplains, impoundments, and depressions.*
- *NWI measurements in Pennsylvania underestimate the occurrence of wetlands by nearly 100% within the Ridge and Valley Province.*

Products:

- *Course developed - "Introduction to Application of the Hydrogeomorphic (HGM) Functional Assessment Methodology," presented to environmental professionals at French Creek State Park, Chester/Berks Counties, PA April 29-May 3, 2002. A second course is planned for spring 2003.*
- *General predictive model of hydrologic characteristics that allows assessment without long-term data collection. (With EPA National Health and Environment Effects Research Laboratory-NHEERL)*
- *Method for coring inland freshwater wetland soils.*
- *Method for assessment of wetland probabilities based on broad geologic features.*

User Community:

- *Environmental professionals from EPA's Regions 2 and 3, the Philadelphia District of the Corps of Engineers, Natural Resources Conservation Service, and wetlands professionals for the states of Delaware, Maryland, Pennsylvania, Virginia, New Jersey, and New York all attended the HGM course given in 2002 and either are using or are preparing to use the results of this research.*

Themes:

Wetlands, Restoration, Multi-criteria/ Multi-discipline Study

The work performed under this grant builds upon prior investigations to develop a list of the cumulative impacts of wetland loss or alteration of biologic and hydrologic processes at the watershed level. Previous studies suggested that both regional landforms and local disturbances have a significant influence on the condition of wetlands within a specific watershed. The work supported by this grant sought to: 1) characterize these influences, 2) determine their effects on natural versus constructed wetlands of varying ages (successional stages), and 3) develop tools to assess the performance of wetland mitigation efforts in replacing natural wetland functions (Cole et al., 2000).

In support of the first objective, the investigators studied the geologic features within numerous central Pennsylvania watersheds to create a wetland probability model. The results of this model were verified in the field and compared to National Wetland Inventory (NWI) maps of the same area. Researchers found that NWI measurements in the Ridge and Valley Province of Pennsylvania underestimate the occurrence of wetlands by nearly 100%; therefore any assessment of an entire watershed will not include the majority of wetlands occurring in the watershed if based on NWI (Cole et al., 2000). To help remedy this situation,

the researchers developed a better estimate of wetland occurrence derived from a combined set of Geographic Information System (GIS) databases and a series of decision rules. Research found that most wetlands in central Pennsylvania are associated with fault zones, with the relative amount of wetland area determined by the porosity of underlying geologic formations. The use of broad geologic parameters for predicting wetland occurrence in the landscape is the first step towards intelligent management of the resources in the area.

Using water level data from over 40 wetlands, the investigators developed a predictive model of wetland hydrologic behavior that managers can use to assess alternative sites for wetland mitigation. The investigators also examined the sedimentation rates at 25 wetlands and found that mineral sediments exceeded organic sediments by 50% overall, though major differences occurred depending on wetland type (Cole et al., 2000). Mineral sediments were dominant in headwater floodplains and impoundments, while organic matter dominated riparian depressions.

Sedimentation rates had a major role in determining the species composition of wetland plant communities. Comparing a number of different communities, the proportion of species tolerant of sedimentation was found to increase with the rate of sediment deposition. The sediments associated with development activities could have significant ecological consequences, as many of these species are invasive and/or exotic in origin.

In support of the second objective, the investigators measured above and below ground biomass associated with created wetlands ranging between 5 and 20 years of age, and compared these values with other values acquired in natural wetlands. They could not discern a relationship between biomass and the age of a created wetland (Cole et al., 2000). Sites that should have been accumulating soil organic matter over time were not, leading them to conclude that some unknown mechanism essential to organic matter accumulation is missing from created wetlands. This observation is not promising for restoration plans.

The research team achieved their third objective by developing an updated wetland Performance Criteria Matrix (PCM). This tool synthesizes data from over 100 reference wetlands in Pennsylvania and can provide its user (managers and decision makers) with a typical range of physical and biological characteristics for an existing or planned site based on the site's landscape position, disturbance, and desired wetland type.

The team also developed innovative tools and field techniques to obtain freshwater wetland soil core samples up to a depth of 50 cm (19.7 inches). These methods have applications that include radiochronologic dating, seed bank analysis, bulk density measurement, and soil contaminants analysis.

They used these tools to obtain 130 samples to evaluate plant community changes over time. Using Cesium-137 as a radioactive marker to date wetland soils, seeds extracted at various soil depths, and historical aerial photographs that documented land use changes in the vicinity of each wetland, they were able to assess the effects of human activity upon the wetland plant community composition. They found that wetlands in highly developed landscapes had more invasive species, fewer rare plants, and accelerated rates of change in plant community species composition as compared to wetlands in other areas (Cole et al., 2000).

This grant also led to the development of a standard monitoring protocol for wetland studies. The protocol has been adapted so that volunteers, such as citizen groups and high school students, can perform the monitoring.

Continued efforts have been made to develop and refine techniques that allow for the assessment of a wetland's condition and to design functional mitigation wetlands if a natural site is lost. The information

collected from this and future projects will continue to be provided to environmental managers and decision makers.

2.2 STAR Grant R825159

Development and Application of Spectroscopic Probes for Measurement of Microbial Activity in Aquatic Ecosystems

Principle Investigators: Carol Arnosti, University of North Carolina at Chapel Hill and Neil Blough, University of Maryland, College Park

Successes/ Lessons learned:

- *Product creates a faster method and new analytical techniques for analyzing the microbial enzyme activities that help drive carbon cycling. These new methods will be utilized in further research.*
- *Method can be used to follow the break down of a wide range of large molecules outside of the cell to better understand the rate at which small, easily degraded molecules can be provided to other organisms in the environment.*

Products:

- *A method of fluorescent labeling of macromolecules and methods to measure hydrolysis in natural systems.*
- *A method to determine the structural selectivity of hydrolytic enzymes.*
- *Creation of new methods that aid in research on carbon cycling.*

User Community:

- *The investigators on this grant are continuing to expand their work at both the University of North Carolina and the University of Maryland based on the results funded by this STAR grant. Other researchers have obtained the publications resulting from this research, but there is currently no documentation as to who specifically may be using this work and in what way.*

Themes:

Microbial Activity, Scientific Techniques

Carbon cycling plays a large role in the global environment and regulates the amount of carbon dioxide (CO_2) in the atmosphere. Human activities produce CO_2 (from burning fossil fuels and the clearing of forests) more rapidly than it can be taken up in the environment. Living plants convert CO_2 to biomass and produce oxygen, but when plants die or are degraded, CO_2 is again returned to the environment. These processes occur in aquatic systems as well as on land. The nature and location of carbon cycling in aquatic systems is a particularly important control on atmospheric CO_2 levels, because aquatic systems have the capacity to buffer somewhat the increase in atmospheric CO_2 levels. This buffering effect is limited however, and an increased level of CO_2 in the atmosphere contributes to the greenhouse effect.

Measuring the rates of carbon cycling in aquatic environments is, therefore, extremely important. The overall carbon cycle involves uptake of CO_2 by aquatic plants (phytoplankton and macroalgae) that harness the sun's energy via photosynthesis to produce new biomass. Much of this new biomass is ultimately converted back to CO_2 as organic carbon is cycled through the food web. Key players in these processes are heterotrophic bacteria, versatile organisms found in every environment that can remineralize both dissolved and particulate organic matter back to CO_2. However, measuring the rate at which heterotrophic bacteria remineralized organic matter is difficult. These bacteria must use enzymes that are excreted outside the cell to break large substrates to sizes sufficiently small to be taken into the cell. The rates at which these extracellular enzymes operate, and the structures that they preferentially degrade, are therefore key controls on the nature and rate of carbon cycling in aquatic systems. The purpose of this study was to develop and test a new generation of sensitive probes to measure the rate of extracellular enzymatic hydrolysis (organic material breakdown) by the bacteria. This research will help

scientists measure the rate at which organic carbon is remineralized to CO_2, a key step in the global cycling of carbon (Arnosti and Blough, 2001).

This study developed a method to measure the rates at which bacteria break down organic material using extracellular enzymes, thus making it possible to transport the material into the cell and leading to production of CO_2. In order to do this, researchers developed fluorescent probes that could be used to make rapid, high-resolution measurements of enzyme activity. The structural specificity of these enzymes can also be determined (Arnosti and Blough, 2001).

These findings provide a clearer method of measuring bacterial enzyme activity in aquatic systems, and thus the overall rate of biomass turnover in a watershed. Factors controlling production of CO_2 need to be measured to determine the influence of natural resource management and land-use practices on the environment. Developments derived during this study have produced new methods of testing levels of organic material consumption, and thus the levels of CO_2 production. These measurements can help determine the major controls governing the dynamics of organic material degradation in aquatic ecosystems (Arnosti and Blough, 2001). Determining these controls can help to develop methods to reduce the amount of, and more importantly the effects of, CO_2 in our environment.

2.3 STAR Grant R825284

Urban Stream Rehabilitation in the Pacific Northwest: Physical Biological and Social Considerations

Principal Investigator: Dr. Stephen J. Burges, University of Washington

Successes and Lessons Learned:

- *Provides a clear system to evaluate restoration approaches.*
- *Evaluates the effects of landscaping practices of streamside residents.*
- *This research helps to evaluate prospective rehabilitation candidates and determining whether rehabilitation goals are realistic.*
- *This data is easy to understand, and highly functional.*

Products:

- *Strategy for pursuing effective rehabilitation.*
- *Evaluation methods for determining the effects of streamside resident behaviors on streams.*
- *Developing a set of products that provide guidance in the field of urban stream rehabilitation.*

User Community:

- *The results of this grant have been distributed to the user community in numerous ways: the Center for Water and Watershed Studies (formerly the Center for Urban Water Resources Management), University of Washington, publishes a quarterly newsletter with a distribution of 3000, including subscribers from academia, all levels of government, tribes, industry/consulting, non-profits, and private landowners, which has carried two to three articles per year since 1998 reporting the results of this study; the University of Washington's Engineering Professional Program conducts short courses in Fundamentals of Urban Water Management, Alternative On-Site Stormwater Management Techniques, and Geology and Geomorphology of Stream Channels, each of which have a mix of government, private, and independent attendees, with 25 to 50% of each course being based on, or modified by, the results from this research; and the Center for Urban Water Resources' Annual Review of Research, presented to approximately 100 agency, consultant, and University scientists, focused from 20 to 50 % of the program on the results of this grant during its active years.*

Themes:

Restoration, Urban Streams

Urban streams are typically degraded streams found in highly populated areas. Society is eager to "rehabilitate" these streams but funds are limited and examples of failed efforts are common. This research examined the urban streams identification process, developed achievable goals for the real world urban and suburban landscape, and finally guided the design of these projects to achieve the goals (Burges et al., 2000). This study also focused on the landscaping practices of the streamside residents; specifically, how they integrated the urban stream in their plans and practices and the overall effect of these plans.

Step 1. Develop a Framework for Rehabilitation Candidates

To evaluate rehabilitation candidates, the variation within the biological condition of the streams was studied. The Benthic Index of Biology Integrity (B-IBI) was utilized on two stream basins in the Pacific Northwest (Little Bear and Swamp Creek). The B-IBI measures five principal groups of attributes (Burges et al., 2001 modified from Karr, 1995):

- Water quality;
- Habitat structure (stream-side plants, channelized depth, or substrate);
- Flow regime (areas of flow, storm drains, impervious/ paved surfaces);

- Energy sources;
- Biotic (living) interactions between fish, hatchery fish, benthic invertebrates and riparian vegetation.

The characterization of the streams can help to evaluate the degree to which rehabilitation efforts can recover lost functions in the stream. Using this method it has been found that streams with large areas of urbanization are more difficult to rehabilitate as compared to streams with little urbanization. Streams in areas that have little urbanization should be rehabilitated first; rehabilitation of streams in areas where urbanization is high is less successful.

When development occurs in lowlands there is more impervious surface (as opposed to pervious surfaces, such as vegetation, which slows and absorbs runoff) creating a greater volume and velocity of stormwater runoff modifying stream flow patterns (the amount of flow in a particular area during a storm). This increase in volume and velocity of the water passing through a stream affects the rate of flood discharge, and increases the amount of flash flooding. Flash flooding scours (erodes) the streambed and banks, dislodging and carrying sediment downstream. As streambanks are eroded, the stream is straightened and the velocity of the water carried by the stream increases and the chance of flooding increases. The amount of stream degradation can help to characterize the overall affect of urban development.

Researchers, decision makers and environmental managers can use the framework developed by this project to create realistic goals for prospective rehabilitation candidates and design rehabilitation projects.

Step 2. Evaluate the Landscaping Practices
The second step of this project concerned the landscaping practices of residents living along the stream. Evaluating the landscaping practices of the surrounding community helps to develop a foundation for the rehabilitation process. Three components were studied to understand the motivations of the residents in their landscaping practices (Burges et al., 2001):

1. Concern for their regional environment -- *Initial findings show and suggest that while residents did take the regional environment into consideration it was not a priority;*
2. Their feelings towards freedom to landscape as they wish on their property – *The control of one's personal space is culturally learned and, although concern for the environment rated higher than personal space, the difference was not statistically significant;*
3. How they took the stream into consideration with their planning -- *Residents tended to focus on the low maintenance aspect of the landscaping without consideration of stream ecology.*

Landscaping practices are a major factor to the urban stream condition, and efforts to affect the streamside public are critical in the rehabilitation process.

Step 3. Develop a Rehabilitation Strategy
The final and third step is to begin rehabilitation. The following strategy (in priority order) was proposed for effective rehabilitation (Burges et al., 2001).

First:	Recognize and preserve the high quality, low development areas.
Second:	Rehabilitate the streams where the full recovery of the stream is possible. This would most likely include areas of low development and low levels of stream health. These areas are easier to find and are easier to correct.
Third:	Rehabilitate areas that are in midrange urban development. While these areas might not have a complete recovery, direct improvement is possible

Fourth: Improve the most degraded streams by finding the cause of the degradation. Restoration of these areas has a small probability of success. Education of the residents, and increased public awareness to the causes and solutions of stream degradation is critical, however, to any progress in these areas.

Some degree of urban stream rehabilitation is a possibility for all areas of the country, but it requires the study of the stream's condition and the evaluation of the sources of degradation. To help reduce the problem, communities should be encouraged to reduce the amount of urbanization adjacent to streams in particular areas. Streamside residents should be encouraged to account for the stream in their landscape planning. Education to change behavior of streamside residents is one key to the rehabilitation of our urban streams.

2.4 STAR Grant R825285

An Integrated Approach to Assessing Water Management Options in a Major Watershed: Extending a Hydrodynamic Water Quality Model to Include Biological and Politico-Economic Components

Principle Investigator: Paul Sabatier – University of California, Davis

Successes and Lessons Learned:

- *This study used several existing models to create a larger, up to date modeling system integrating hydrodynamics, water quality, fishery distribution, and economics to determine the effects of management decisions.*
- *The investigators worked with elected and appointed officials and decision makers to develop the integrated sets of models.*
- *Many elected and appointed officials were interviewed to better understand the political context for water decisions and how water decisions are made.*
- *The Consumnes Research Group was created as an outgrowth of this study and focuses on monitoring and research needs within the Sacramento and San Joaquin River Watershed*

Products:

- *A model that can aid in the prediction of the effects of management alternatives on hydrodynamic and water quality characteristics.*
- *CALVIN model for economics for urban and agricultural water use with environmental use. http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/*

User Community:

- *A decision support system for Regional Water Quality Control Boards was developed to map impairment data and is being used to prepare California 303(d) reports and to support preparation of TMDL assessments by Regional Water Boards and U.S. EPA Region 9.*
- *A Water Quality Standards Inventory Database was published in collaboration with the California Department of Transportation (CalTrans). Subsequent funding from EPA, CalTrans, and the North Coast Water Board has allowed development of models using Landsat and airborne hyperspectral input to assess the impacts of road building, forestry operations, and landslides on sedimentation rates.*
- *The California Department of Water Resources (DWR) is utilizing concepts developed by this grant. Experience gained from this project is being used by DWR to guide the addition of fish behavior to its particle-tracking model and delta geometry developed by the project is being provided to DWR for its use. DWR is also interested in the results regarding striped bass larvae in various flow/management scenarios.*
- *The results of model-generated maps have been used by the Wildlife Conservation Board to identify priority projects for acquisition and restoration using bond funds.*
- *Methods developed by this project are being used by California EPA's Department of Pesticide Regulation to determine annual pesticide inputs into the stream network.*
- *GIS tools developed with partial support from this grant are being used by the Department of Health Services to prepare assessments to drinking water under the Source Water Assessment Program, Safe drinking Water Act. The state is also using maps developed as part of this grant for its submission to the Clean Water Action Plan.*
- *Other potential users include the California Fish and Game Commission and the National Marine Fisheries Service for planning recovery of endangered salmon, including delineation and restoration of critical habitat.*

Themes:

Economics, Harmful Toxins, Policies and Politics

There are many problems that occur when managing large-scale watersheds that are subject to conflicting demands between traditional water users and those seeking to restore damaged fisheries. This research hoped to develop and demonstrate a way to assess management alternatives for watersheds that also support species at risk (Sabatier et al., 2002). Studying management alternatives helps to develop plans that aide major watersheds but are also biologically, politically, and economically sound.

This study tested the responses of three fish species sensitive to hydrodynamic influences, changes in water quality, and ecological influences under different management practices (Sabatier et al., 2002). Different management processes studied include: restoration of riparian habitat, regulation of stream flows, rescheduling of water diversions from the river (pathways used by trout to bypass dams), and control of point and non-point pollution sources. This study expanded and integrated a previously constructed model of a Californian river and delta system, to include habitats in estuaries and riparian areas and ecosystems native to the area, the contaminants and inflow from tributary watersheds, the economics of agricultural and urban water use, and the affects of all of these on fish populations. Using this new set of models one can explore the impacts of a variety of management scenarios to optimize fish populations with agricultural and urban water demands.

With the information found in this study, better management decisions can be made that affect fish populations positively and take into account agricultural and urban water demands. Two management scenarios for the area studied were developed through this research: a scenario for normal precipitation years and one for dry years. The management plans involve a reallocation of water from irrigated agricultural lands to fishery purposes and an "isolated facility" that diverts water via aqueducts from the Sacramento River north of the delta, around the delta, to State and Federal water projects. The main strategy involved with these plans is to first use economic models (such as CALVIN) to determine the most efficient allocation of water reductions across farming regions, then use hydrodynamic and water quality models to determine the impacts of the flow diversions, and finally use fishery models to determine the impact on the local fish species. In evaluating these management scenarios using the criteria presented above, it was determined that the "isolated facility" was a relatively clear tradeoff between benefits to water users and costs to fisheries.

Management alternatives were provided from the work of either CALFED (a consortium of state and federal agencies and stakeholders) or the Central Valley Project Improvement Act of 1992. These alternatives include: (1) channel enlargements that would allow expansion of the capacity of the pumping plant at the head of the California Aqueduct (a primary component of the California State Water Project); (2) an isolated canal with a capacity of 5,000 cfs up to 15,000 cfs that would convey water from the North Delta, around the Central Delta to export facilities in the South Delta; and (3) connection between state and federal pumping projects in the South Delta designed to reduce entrainment and other harmful effects on sensitive species by increasing operational flexibility (e.g. allowing alternative diversion locations and at times, among others).

Although this project is based on the Sacramento River and Delta system, and its corresponding organisms, the results can be used to evaluate other river systems to determine the best management plans for those rivers. With an analysis of fish and the evaluation of hydrodynamics and water quality in the local area these research results can be used in many different environments. The results of this study will be particularly advantageous in regions of the mid-west that have large populations of salmon and trout.

The CALVIN model is available online and the Consumnes Research Group is actively continuing the research.

2.5 STAR Grant R825286

Effectiveness of Regulatory Incentives for Sediment Pollution Prevention: Evaluation Through Policy Analysis and Biomonitoring

Principal Investigator: Seth R. Reice - University of North Carolina at Chapel Hill

Successes and Lessons Learned:

- *The results of this study can guide managers in determining the most effective regulation plans for construction sites near water sources. This is in an effort to reduce sedimentation, which degrades water quality, and reduces aesthetic and economic value.*
- *Many developers and enforcers contributed to this study to help determine the best, acceptable methods.*
- *The frequency of the on-site inspections and the swiftness and severity of enforcement procedures are key concepts in regulation*.

Products:

- *A chart displaying the effectiveness of various types of regulation and their effectiveness.*

User Community:

- *The results of this grant have been presented to the North Carolina Stormwater Management Consortium; the North Carolina Sediment Control Commission; and Taskforce 5, Agricultural Pollution, of North Carolina Sediment Commission (two occasions). Additionally, presentations have been given at the following conferences: the 1998 Annual North Carolina Water Resources Research Conference; the 1998 Western North Carolina Erosion and Sediment Control Conference; the 2000 National Conference on Tools for Urban Water Resources Management and Protection; and the 2000 North Carolina Soil and Water Conservation Conference. Presentations have also been made to ecological and benthological societies and universities in the United States and Europe.*

Themes:

Urban, Policies and Politics

A critical problem in American rivers and streams is sedimentation. Sedimentation degrades the water quality, alters the habitat for fish and macro-invertebrates, limits ecosystem functions and services, and reduces the aesthetic and economic value of our rivers and streams. Many regulations and policy incentives have been devised to control sediment pollution in rivers during construction in the area. This research studied various regulatory procedures and the overall effects of sedimentation on the stream ecology before, during and after construction. The researchers posed one main question: What combinations of policies, regulations, and onsite inspections really work to enhance stream and ecosystem health? The major goal of this study was to create more effective management strategies to provide sustainable development (environment, social, and economic) of watershed areas under construction (Reice and Andrews, 2000).

Overview

In the study 17 streams were sampled before, during and after construction. Samples were taken at the site, 100 meters upstream, and 100 meters downstream from the site (Reice and Andrews, 2000). Each sample was tested for its benthic (stream bottom) community level data, the water chemistry (including pH levels) and the decomposition of leaf litter. The 17 streams were located in three different counties in North Carolina, each with different county regulatory procedures. Regulatory procedures involve onsite inspections, the speed of enforcement, and the severity of enforcement. Interviews were conducted with the developers and the inspectors to find their opinion of different types of regulatory procedures as well.

Findings

Hypothesis 1: Stronger erosion and sediment control regulation will result in less damage to streams.
Differences in laws and regulations requiring erosion and sediment control have a limited impact on stream condition (Reice and Andrews, 2000). The key seems to be the frequency of the on-site inspections and the swiftness and severity of the enforcement procedures.

Hypothesis 2: Tighter enforcement and sediment control laws will result in less damage to streams.
Reice and Andrews (2000) show that the nature and intensity of the enforcement does matter. With more frequent inspections and more severe penalties there is significantly less degradation of the stream. More frequent inspections and a cooperative, flexible approach effectively limit the damage to the stream communities. The certainty of punishment is also a strong incentive to maintain erosion control procedures on site.

Hypothesis 3: Small construction sites will cause more stream degradation than large construction sites.
Small sites do actually cause more stream degradation than large construction sites; smaller areas are often only required to install silt fences that are commonly installed incorrectly and frequently fail (Reice and Andrews, 2000). In many areas, developers of small sites are not required to take as extensive erosion and sedimentation control measures as those required for larger sites. Smaller sites are also subject to fewer on-site inspections than larger sites.

Hypothesis 4: There is greater degradation at the construction sites, less downstream and no changes upstream.
The upstream conditions of the streams are used as "normal" comparisons for the on-site locations and the locations downstream (Reice and Andrews, 2000). On-site locations were dramatically impacted; the effect is sometimes reduced downstream but often persists.

Conclusion

Each of the three political jurisdictions studied differs in the stringency of its sediment and erosion control requirements and the nature and intensity of enforcement of its regulations. The study showed the effectiveness of these methods for regulating sediment on construction sites. One jurisdiction is flexible with the developers, but provides input to them and takes the initiative to assure good sediment and erosion control. This jurisdiction has severe penalties (although they are rarely assessed), resulting in a high level of compliance with the regulations. Another jurisdiction subjects its developers to frequent on-site inspections and limited penalties, also resulting in a high level of compliance to the regulations. The third jurisdiction actively imposes minor penalties, but inspectors spend little time on each project, resulting in a lower level of compliance with its regulations. It was also observed that as the number of construction sites for which each inspector was responsible increased, there was a decrease in the compliance with regulations because as the regulators' workload increased their task became more difficult and resulted in less enforcement of the regulations.

There are a few easy ways to create more effective management strategies to solve the problem of sedimentation in our streams, which degrades the water quality, limits ecosystem functions and services, and reduces the aesthetic and economic value of our rivers and streams. First, on-site inspections for all construction sites, large and small, should be frequent; this encourages the developers to comply with the regulations and policies. Acts of enforcement must be swift and strict. A threat of a " Stop Work Order" will motivate any developer to abide by the regulations. In addition, a close working relationship between the developers and the inspectors should be reached. Both may need to compromise to get the job done while protecting stream quality. With these adjustments, sedimentation in streams and rivers due to

construction can be greatly reduced, resulting in an environmentally sustainable development of the watershed.

2.6 STAR Grant R825289

Geochemical, Biological, and Economical Effects of Arsenic and Other Oxyanions on a Mining Impacted Watershed

Principle Investigator: Glenn C. Miller - University of Nevada- Reno

Successes and Lessons Learned:

- *Mining sites that have been abandoned can produce contaminants that enter the water system and travel downstream to agricultural and recreational areas*
- *Numerous relationships formed between the investigators, EPA Region 9 personnel, and the regulatory and mining communities during this study, which will continue into the future because the issues in the project remain very important for mining impacted areas.*
- *The topics of the two workshops held as part of the grant were very timely, but the interest and effort expended on these topics has increased since the grant ended.*
- *One pit-lake has developed since completion of the grant and the conceptual model developed as part of the grant has been shown to accurately predict the amount of oxidation products that would be released into the pit-lake.*

Products:

- *Models of the concentration and transport of contaminants.*
- *Surveys of many local residents.*
- *A pit-lake workshop was developed in Nevada in March 2000 and was attended by 260 persons from the mining, consultant, regulatory, and academic communities.*
- *Two hundred and fifty people attended another workshop entitled "Closure, Remediation, and Management of Precious Metal Heap Facilities."*

User Community:

- *The two workshops focused on closure of precious metals heaps and the prediction of water quality in precious metals pit-lakes. The organizations attending these workshops included: the Bureau of Land Management; the U.S. Forest Service; the U.S. Fish and Wildlife Service; the U.S. Geological Survey; the Nevada Division of Environmental Protection; the mining industry and its consultants; and several environmental organizations (Mineral Policy Center and Great Basin Mine Watch). The STAR Grant investigators continue to have regular interactions with the mining industry participants and are expanding research begun during the STAR grant. The results of this grant have allowed the environmental community to focus on issues of significance, rather than on non-issues, and have resulted in a more focused regulatory effort.*

Themes:

Restoration, Economics, Toxins, Politics and Policies

Background

According to the Nevada Bureau of Mines, gold mining in Nevada has increased in recent years due to modern methods of extraction and now accounts for about 65-75% of the nation's production (Miller et. al., 2001). This large increase from previous years can be attributed to the mining of large deposits of low-grade ore using new heap leaching methods of recovery that evolved in the 1970's. Research conducted under this grant considered the environmental problems that have been introduced as a result of these new mining methods (Miller et al., 2001). The study was focused in the Humboldt River Basin in Nevada, but can be useful for other U.S. mining states with a focus on large-scale extraction of metals.

The dramatic expansion of new mines in the last 20 years is now resulting in a large number of mine closures as the ore is mined out (Miller et al., 2001). While mining is active, the excavation site is

continuously dewatered. This is accomplished by pumping the water that accumulates from groundwater and rain, into nearby streams, allowing the extraction process to take place in relatively dry conditions. A mine closure results in the secession of dewatering and leaves a pit, which fills with water in the years and decades in the future. Closure of a mine includes a stabilization of chemical and physical properties of the area and is designed to allow the land and resources to return to uses that existed prior to mining. This closure scenario is, however, often not possible and some mines are likely to require very long term maintenance and water quality management to prevent contaminants from being released to the surface or groundwater. The research in this study evaluated four problems:

- Drainage of contaminated water from heaps (areas where cyanide was used to extract low-grade metal from the soil);
- Pit-lake water quality (quality of man-made lakes, created from the filling of open pits);
- Economic issues of dewatering;
- Effects on wildlife from exposure to arsenic (a waste product of extraction mining where the land has not been returned to its previous state).

This study allowed researchers to examine environmental issues associated with mining and encouraged others in the mining industry to find solutions that are less damaging to the environment but can be accomplished in a cost effective manner (Miller et al., 2001).

Findings

Contaminated water from Heaps

In Nevada alone, between one and two billion tons of heap material, resulting from precious metal extraction mining using cyanide, will be abandoned in the next five to ten years (Miller et. al., 2001). Water from rain or snowmelt leaches contaminants from the abandoned heaps. This drainage water contains a variety of contaminants, including arsenic, antimony, selenium, and sulfate. Studies have shown that by controlling the pH levels (within midranges of 2-10pH) in the heap leachate, the adsorption behavior of some of the contaminants can be controlled, thus reducing the amount of contamination. Studies also showed that incorporating a cover to reduce the flow of water into the heap would have a significant effect on reducing the total mass of contaminants leached from the heap.

Pit-Lake water quality
When mining is completed and dewatering of the pit ceases, groundwater flows into the pits and standing bodies of water (artificial lakes) will form. The study used an older pit-lake for research because very few pit-lakes presently exist and the basis for predicting long-term pit-lake water quality is mostly hypothetical. Studies showed that the pit-lake was not very different from other lakes in the region. Pit-lakes had a slightly basic pH and varied levels of arsenic and selenium (Hershey et al 2000). The results suggest that concentration of containments in pit-lakes due to evaporation of the water in them may be an important factor contributing to overall levels of metal concentrations, but more testing needs to be conducted on the chemical processes that occur in the lake.

Effects of Arsenic on Aquatic Organisms
This study researched the effects of arsenic on aquatic organisms in the presence of ultraviolet (UV) radiation from the sun. This is important because aquatic systems are exposed to varying levels of UV light constantly. Researchers studied the survival and ability to create viable offspring of crustaceans in various arsenic and UV conditions. Results showed that the survival rate of the crustaceans was affected only when relatively high levels of UV and arsenic were present. This research points to the importance

of using realistic UV exposures when testing survival rates, and gives a more adequate description of the affects of arsenic in aquatic habitats.

Economic Impacts

Miller et al. (2001) cites three studies summarized by Shaw and Netusil, which were conducted to evaluate the overall downstream impacts of dewatering:

- A travel cost analysis using existing data (an approach that uses the public's desire to travel to a particular destination despite long distances as a surrogate for estimated cost/value) was conducted (Huszar et al., 1999b). Dewatering of the mines stabilizes downstream flow and keeps the reservoirs full. The travel cost analysis examined a downstream reservoir to determine the value of visits made to the reservoir during dewatering of the mines verses visits once dewatering stopped. It was determined that during dewatering $100,000 per year in additional revenue would be created from the increase in visits to the reservoir. But once dewatering stops, the reservoirs are no longer full because there is no longer a consistent supply of water to them and the consumers' surplus is lost from downstream users.

- A programming analysis was conducted to obtain the shadow values (environmental impacts of various management decisions expressed in monetary terms) in agricultural production. The model evaluated the impacts (gains and losses) on downstream agricultural users. The model allowed for changes in planting/ harvesting alfalfa (crop yield) due to stream flow, but not for changes in irrigation patterns. With dewatering, the value of agricultural land in environmental terms (shadow price) is five times greater ($192/ acre/year) in the first year being modeled than under historical pre-dewatering flows (Lambert and Shaw, 2000).

- A telephone valuation survey was also conducted to determine the willingness to pay for two programs related to dewatering. The respondents were first asked a question pertaining to the support of a continuation of the benefits from dewatering and then asked about their willingness to pay for a support program if the initial program fails and pit-lakes are created. By studying revenues generated by a nearby reservoir it was determined that a created pit-lake would only generate about $500,000 per year in new revenues (Huszar et al., 2001).

Pumping costs run in the millions of dollars per year, which would indicate the total value to downstream parties estimated above could not generate adequate revenues to economically justify continued pumping into the future.

This research showed some of the negative effects of pit mining in watershed areas (Miller et al., 2001). In addition to the run-off of harmful contaminants into pit-lakes and the watershed, costs for dewatering of pit-lakes, and use for recreational activities were researched in this study. Although long-term effects are not entirely obvious, the short-term effects of mining in watershed areas on the chemical composition, biology, and economy are not promising. Important environmental issues associated with mining can now be brought to the attention to regulators and members of the public to focus on these problems and help form environmentally and economically sound solutions.

2.7 STAR Grant R825290

Integrating Modeling and Management of Agriculturally-Impacted Watersheds, Issues of Spatial and Temporal Scale

Principal Investigator: Patrick Brezonik - University of Minnesota

Successes and Lessons Learned:

- *Scientists tend to develop models that address cumulative effects at large scales while managers need to make localized decisions due to policy shifts. Therefore, the smaller agroecoregions are a useful aid to watershed managers.*
- *Targeting regions to reduce non-point pollution is cost effective.*
- *Residents surveyed were willing to pay increased taxes and water bills to reduce levels of phosphorus pollution.*
- *Watershed management in highly agricultural watersheds will be most effective when watersheds are complemented by agroecoregions to identify and target regions where specific combinations of BMPs for agricultural sediment and nutrient abatement are most suited.*

Products:

- *Computer models were created along with statistical evaluations of long-term stream, lake, and groundwater data.*
  (Available from website: http://www.soils.umn.edu/Research/research5.htm)
- *An eight-step process to aid decision makers to identify, assess and implement restoration measures in agriculturally intensive watersheds was created.*
- *Farmers were surveyed to explore the magnitude of transaction costs in the context of potential strategies to reduce agricultural pollution.*

User Community:

- *The Minnesota Department of Agriculture (MDA) is developing best management practices (BMPs) to protect water quality within each agroecosystem as determined by this grant. Grant researchers helped the Natural Resources Conservation Service estimate the transaction costs of installing conservation practices nationally. The Minnesota River Basin Data Center, Minnesota State University, has a GIS data file containing the agroecosystems on its web site. The Minnesota Pollution Control Agency, with MDA and U of M, is developing an instructional manual to identify the most appropriate BMPs by basin, ecoregion, and agroecoregion as part of its goal to Encourage Understanding of Origin and Remedy for Nonpoint Source Pollution Problems. The Basin Alliance for the Lower Mississippi in Minnesota (BALMM) is promoting the development of nutrient management plans that are consistent with and adaptive to the agroecosystems within the basin. The Minnesota Department of Natural Resources, the Minnesota Valley National Wildlife Refuge and several environmental advocacy organizations are also use results derived from this grant.*

Themes:

Multi-Criteria Study, Agriculture, Economics, Politics and Policies

Long-term, large-scale research studies and models often do not meet watershed managers' needs. Scientists are addressing cumulative effects over large areas and long timeframes, but policy shifts are forcing managers to make decisions on a more local and short-term basis. Effective implementation of watershed management principles requires that models incorporate knowledge about effects at longer time frames and larger areas into more localized decision-making. This study researched the usefulness of smaller scale land units or agroecoregions instead of large watershed units typically used for watershed management (Brezonik et al., 2001). Agroecoregions are landscapes within watershed areas with uniform crop productivity, climate, geological material, soil drainage, and slope steepness (there are usually about

two agroecoregions per watershed). The study compared economic, stream ecology, aquatic chemistry, and soil science findings between the typical watershed areas and the smaller agroecoregions.

Findings

Agroecoregions were a useful study unit to address trends and aid in watershed management. Economically, it is more cost effective to reduce pollution in watershed areas by first targeting the specific regions or practices from where the pollution originates (Brezonik et al., 2001). Dividing watershed areas into agroecoregions facilitates the targeting of problem areas. In stream ecology the biological composition tends to be more strongly influenced by local habitat; therefore, dividing the watershed into agroecoregions creates less variability in results. The standard variation in results is also reduced when aquatic chemistry is measured at finer scales. Furthermore, when smaller scale landscape units were used, findings became more useful to natural resource managers in establishing regionally specific water quality goals and prioritizing their use of funds. In stream ecology, aquatic chemistry and landscape analysis, using reduced areas (agroecoregions) produced more noticeable trends useful for implementing watershed management plans.

Smaller land areas are also useful for predictive modeling in scenario analysis. Using models, simple and rapid methods can be developed to provide tools for watershed management. For example, this study showed the effectiveness of conservation tillage on highly erodible land.

Implications

In this study, subdividing the basin's watershed into agroecoregions enhanced predictability of stream water quality parameters (Brezonik et al., 2001). This approach can help target cleanup efforts to the most sensitive soils and landscapes within the most critical watersheds. This study showed that some indicators of water quality functioned better at the finer scale of agroecoregions or by areas defined by the intersections of agroecoregions and major watersheds than by watersheds alone. Watershed management in highly agricultural watersheds will be most effective when watersheds are complemented by agroecoregions to identify and target regions where specific best management plans for agricultural sediment and nutrient abatement are most suited.

An eight-step process was developed by researchers in this study to aid decision-makers with identifying, assessing and implementing restoration measures in agriculturally intensive watersheds (Brezonik et al., 2001):

1. Identify the problem in the area
2. Monitor the water quality
3. Evaluate the pollution sources
4. Set water quality goals
5. Identify the land characteristics that are affecting water quality
6. Prioritize watersheds and target specific agroecoregions within watersheds
7. Identify Best Management Practices (BMPs) and approaches that are cost-effective in improving or maintaining water quality
8. Implement BMPs and monitor progress toward goals

This plan manages landscapes or environments comprehensively while still incorporating the unique requirements of local resources and communities. Using this plan will help to integrate long term goals of scientists with the short term desires of the decision-makers and the community.

2.8 STAR Grant R825306

Watershed Protection in Agricultural Environments: Integrated Social, Geomorphological, and Ecological Research to Support Ecosystem- Based Stream Management

Principal Investigator: Dr. Bruce L. Rhoads, University of Illinois

Successes and Lessons Learned:

- *This study integrates the values of farmers and stakeholders with geomorphological and ecological data (stream channelization).*
- *The investigators determined the importance of linking scientific understanding with social factors motivating farmers to influence agricultural practices.*
- *Educating farmers with scientific information must be done in a manner that recognizes the value system of farmers and how and why it varies from that of environmental scientists.*
- *Meandering streams are better for fish abundance and biomass than straight channelized streams.*

Products:

- *Determined methods that impede and facilitate infusion of scientific knowledge to farmers*
- *Charts and diagrams available from study*
- *Results of interviews with farmers of the region regarding their professional issues and how they perceive scientific research and findings*

User Community:

- *The Natural Resources Conservation Service's District Commissioner will be presenting the results of this grant at their summer training sessions. Other users include the Illinois Department of Natural Resources, the State Farm Bureau, and the State Drainage Districts.*

Themes:

Agriculture, Politics and Policies

Many farmers have a difficult time using scientific research results on their land because farmers often feel the scientists' opinions are insensitive and not very understanding of farmers' every day concerns. However, research shows that many practices traditionally used by farmers negatively impact the environment. The work performed under this grant sought to integrate the social and ecological aspects of watershed protection in agricultural areas of the Midwest and can be used for other regions of the United States where agricultural impacts on watersheds are a concern. This research studied the effect of agriculture and biomass (the amount of living material within an area) in human-modified, channelized streams verses natural un-channelized streams (Rhoads et al., 2001).

History

Wetlands historically were thought of as wastelands, places where viable produce could not be grown. As settlers used the land for cattle they discovered that wetland areas were very fertile and good for crops and soon attitudes changed. Farmers began to drain the land and this practice slowly became institutionalized. Presently many farmers still practice wetland draining and feel that well maintained drainage increases farm productivity and is an aesthetic element of a well-kept farm.

Farming Today

Today, after 150 years, farmers still use wetland drainage and other techniques of farming (e.g., farming to stream edges, chemicals [fertilizers, pesticides], and adaptations to "no-tilling" laws) despite advice from local scientific authorities (Rhoads et al., 2001). Open-ended interviews show that farmers view

themselves as true environmentalists and people of the land and do not easily change their ways (Rhoads et al., 2001). The interviews showed that some farmers view the suggestions and opinions of scientists as insensitive and uncaring of the farmer's life and concerns. Farmers today know that they are an important part of society, but they feel that they are often not viewed this way by society. In the Midwest particularly, farmers feel that they have little political power and are not given the respect they deserve. Previous studies have shown that cooperation is an effective way to develop mutually beneficial environmental solutions. Many different aspects come into play, including historical context, economic context, legality, and scientific and local knowledge. These aspects combine to integrate the values of both the scientist and the local farmers to develop a common understanding (Rhoads et al., 2001).

Effects of Land Use and Channelization

Research was done in East Central Illinois, a distinctive agricultural landscape in the Midwestern United States, on the watersheds and streams (Rhoads et al., 2001). The different types of fish within the stream's riparian area and the stream's geomorphic features were studied. Most farmers convert streams into straight drainage channels while natural streams tend to meander. Streams in the upper Embarras River basin were studied to determine the differences between the natural meandering stream and the human-influenced straight stream. It was discovered that the meandering streams have greater variability in the general geomorphic features over time and space, resulting in greater habitat diversity and fish abundance than in the straight streams.

Summary

This research has improved the understanding of the concerns of farmers involving the opinions and suggestions of scientific research in East Central Illinois (Rhoads et al., 2001). Environmental information provided for the farmers must be delivered in a manner that recognizes the value systems of farmers. Farmers in general need to understand that updating their methods will, in the long run, save their land and allow their farms to remain profitable.

The research also improved understanding of the connection among geographic morphological conditions (the conditions of plant and animal life in an area), physical habitat and biodiversity in natural streams and human influenced streams. In particular research shows how complexity in stream types affect the diversity of habitat. These findings can be used to teach farmers how draining can affect the land and the biomass in the area (Rhoads et al., 2001).

Organizations such as the USDA-NRCS (US Department of Agriculture-Natural Resource Conservation Service) are available to aid farmers in transitioning to a more environmentally sound farm by assessing the land's resources, drawing on the scientific contributions relevant to the needs of the area, and working closely with land-users to develop plans that mesh with predetermined objectives. When farmers can see how watershed draining and channelization affects their land, they will be better able to understand the implications of their farming practices, and will be motivated to change their methods to improve their environment.

2.9 STAR Grant R825335

Modeling Effects of Alternative Landscape Design and Management on Water Quality and Biodiversity in Midwestern Agricultural Watersheds
Principal Investigator: Mary V. Santelmann - Oregon State University

Successes and Lessons Learned:

- *This study evaluated alternative futures of agricultural watersheds based on a process of involving a diverse array of disciplinary experts in the future landscape design.*
- *Ecological and economic analyses of these small (5000-8000 ha) watersheds indicated that some changes in land use and agricultural practices result in environmental improvements and increased profitability of the enterprise.*

Products:

- *Species habitat association matrices were developed for non-fish vertebrates, butterflies and plants.*
- *Spatially Explicit Population Models (SEPMs) were developed to explore the potential for alternate land use and management options to restore native biodiversity (Clark and Danielson in review).*
- *Existing models were also employed to characterize the potential effects of landscape change on amphibian populations (Rustigian et al. in press) as well as all native vertebrates, butterflies, and plants (Freemark et al. in prep., Santelmann et al. in prep.).*

User Community:

- *Lessons learned from this grant were presented to the Illinois EPA and the Illinois Department of Natural Resources (IDNR), and influenced the design of an alternative futures project that is being sponsored by U.S. EPA Region 5, U.S. EPA's National Wetlands Program, the IDNR and Kane County, Illinois. Future land use scenarios, including stream corridor and wetland conservation, were developed for the Blackberry Creek watershed (Fox River Basin) by a local landscape architect.*
- *The EPA Region 10 liaison for salmon listings has inquired about this project and may use the results in his work.*
- *Interest by the Forest Science Lab in Lincoln, NB resulted in a workshop at the 2002 International Association of Landscape Ecology's annual meeting.*
- *Scientists participating in the Scientific Consulting Group Workshop (on interdisciplinary research), U.S. EPA STAR program, were informed about this project in October 2000.*
- *Numerous educators are using the results of this grant in both graduate and undergraduate courses, with attendees from the fields of resource geography, fisheries and wildlife, forest science, marine resource management, botany and plant pathology, economics, ecology, rural studies, and landscape architecture.*

Themes:

Agriculture, Economics

This study focused on the design and evaluation of future scenarios associated with a range of human land use and management choices for watersheds. The findings can be used to plan for future uses of agricultural land and to guide research on changes that may need to be made in order to improve the long-term outcome of these uses. Changes in the economic profitability of enterprises in the area were studied along with overall change in water quality and biological diversity for a well-rounded assessment of effects of alternative landscape design (Santelmann et al. 2001 and Santelmann et al. in review).

Water Quality

The Soil and Water Assessment Tool (SWAT) model (Arnold et al. 1995) was calibrated using data collected from the study watersheds, and used to determine the potential effects of alternative agricultural land use practices on surface water quality with respect to sediment and nutrient transport (Vache et al. 2002). Suspended solid and nitrate concentrations remained extremely high in the watershed under current land use and the scenario that focused on agricultural production. In the futures designed to restore water quality and enhance biodiversity, concentrations of solids and nitrates were reduced by 30-75% of existing exports (depending on the watershed and scenario). To help reduce nutrient export, it is important to reduce input of nitrates and restore or construct wetlands in key locations where tile drainage is received before entering streams. Modifying land use practices such as grazing in the riparian zone and maintaining perennial cover near and within the riparian zone were practices related to reductions in erosion-related water quality problems.

Biological Diversity

Non-fish vertebrates (mammals, reptiles and amphibians) and butterflies were studied to determine the effects of changes in land use and management practices on biological diversity in a watershed. Species-habitat relationships were established and model-runs with sensitivity analyses were performed (Rustigian et al. in press, Freemark et al. in prep.) Plant biological diversity was studied as well, with a focus on species-habitat associations and evaluation of future scenarios (Santelmann et al. in prep.). Scenarios were tested for their potential to conserve or restore native biodiversity in watersheds. The effects of nutrient loading from agricultural runoff on wetland plant diversity were also studied in controlled experiments with native and invasive plant species. It was determined that biological diversity can be restored when habitat for the native species is created. However, in the modeling study of all of the mammals found within the watershed, competition for resources (and other interspecific interactions) were found to be as important as habitat area in influencing population growth and persistence for some species.

Economic Analysis

The profitability of farming was researched for three different policy scenarios (Coiner et al. 2000, Santelmann et al. 2001). Crop yields were projected for the next 30 years and were compared to the current profitability of farming. Economic analyses of the small watersheds tested, indicated that some changes in land-use and agricultural practices result in environmental improvements and increased profitability of the enterprise, while others involve tradeoffs between economic and environmental objectives. There might also be tradeoffs among different components of environmental quality or different components of water quality improvements.

Different styles of agricultural management produce different effects on the land in the area. For example, using conservation tillage systems rather than conventional or traditional tillage methods tends to allow more weeds and a higher nitrogen leaching rate, but causes less disruption of animal life cycles. Traditional tillage methods have a higher rate of soil erosion and soil compaction as well as an overall higher fixed cost for machinery and maintenance. Comparing conservation tillage to no-tillage, no-tillage reduces erosion and is less expensive, but includes a variable cost for weed control. Ecological principals and guidelines must be incorporated into land-use and management decisions on agricultural land and the aquatic systems to which they are linked. To make land-use decisions, managers and the farmers should incorporate plans for the future in their ideas for today.

2.10 STAR Grant R825381

Integrated Urban Watershed Analysis: The Los Angeles Basin and Coastal Environment

Principal Investigator: Richard Turco – University of California, Los Angeles

Successes and Lessons Learned:

- *This study integrated four major components of a coastal urban region: air, land, wetlands, and ocean; all play a role in the overall quality and supply of water to an area. They interact and affect levels of pollution in the system.*
- *There are different types of indicators available and different methods of evaluation of watershed components and relationships, including differences in spatial measurements and watershed components.*

Products:

- *Graphics in final report of all steps in project including charts and diagrams suitable for use by decision makers*
- *Development of a regional ocean modeling system.*
- *Links four main components of an ecosystem (air and atmospheric processes, land and hydrological processes, wetlands and ecological processes, marine and coastal processes) to evaluate water quality in a major urban watershed.*

User Community:

- *Academic Community, Water Agencies, Environmental NGOs*

Themes:

Wetlands, Multi-Criteria Study, Urban

Water availability and quality in major cities such as Los Angeles (LA) are major environmental concerns. It is important to understand many aspects of the water resource problem in order to see the entire picture. This includes regional meteorology, vegetation and land use, basin hydrology, water consumption and disposition, runoff sources, and toxic and nutrients loads. This study used monitoring data and existing models to investigate the processes that control water quality in a major urban watershed. The research results will contribute to other studies aimed at scientific understanding of the watershed system, environmental impact assessment, or restoration and mitigation schemes, and can be used as a model for various urban regions (Turco et al., 2002).

Part of the effort has focused on the key components of the problems in watersheds. The component analysis has been divided into four main areas; air and atmospheric processes; land and hydrological processes; wetlands and ecological processes; and marine and coastal ocean processes (Turco et al., 2002). For the present study, these components were linked in an assessment of the sources and distributions of key pollutants in Santa Monica Bay, which is influenced by several large watersheds.

Air. The Air component of the LA Watershed project considered atmospheric processes that significantly influence the coupled system of land, wetlands and coastal ocean and the flow of water and pollutants through that system. Precipitation levels provided information on the distribution of precipitation among the major watersheds in the region as well as detailed rainfall data for hydrologic simulations. A regional climate record was also fully reconstructed. This record is useful for estimating potential extremes in precipitation and corresponding stream flow to the coastal zones. Using models, a three dimensional view was also created that shows how elevated pollutant layers can form over the Los Angeles Basin (leading to pollutant disposition on inland headwaters). This demonstrates the various pathways by which urban pollutants are dispersed over other areas adjacent and even remote.

Land. The Land component of the LA Watershed project sought to develop predictive models representing the physical, hydrological and runoff characteristics of the watersheds that feed the coastal waters. Watersheds were characterized using detailed information on elevation, land use, vegetation type, and soil properties collected from regional agencies. It was determined that pollutant inputs to coastal waters from stormwater are greater than inputs from treated wastewaters, suggesting a future focus on limiting the number and concentration of contaminants in stormwater. Biological diversity (both animal and plant) is also affected by the water sources and the amount of development in the urban area. Most of the area's vegetation is fed by water imported through irrigation, which can influence the microclimates in urban neighborhoods and can impact the overall air quality. Native vegetation is found in pockets of non-irrigated habitats; however, extensive channeling of waterways has reduced the opportunity for stormwater to hydrate the area. The animal life in the urban area is affected by the widespread use of pesticides and herbicides that affect the native habitat of the area. Species that are more reliant on large areas of native habitat are in a more precarious state. Only adaptable species like raccoons and squirrels are still found in areas with native vegetation.

Wetlands. The L.A. Watershed project Wetland component examined the fate, transport and ecosystem effects of chemical substances in certain important watersheds along the coast. The main objective was to determine how pollutants affect the area and its associated resources. In highly urbanized zones, land runoff typically contains a substantial burden of pollution associated with development and land-use patterns. It was found that due to a high level of nitrogen in the water, algal growth was increased. On the other hand, low levels of nitrogen in the sediment were measured. The effects of different amounts of chemical pollutants on the abundance and population dynamics of estuarine fish were evaluated, although specific thresholds on the amount of pollutants and the pollution effects were not established. The degradation and destruction of the tidal wetlands in the area have reduced the natural ability of these ecosystems to cleanse land runoff of pollutants. The resulting pollution leads to a severe and continuing decrease in the amounts of dissolved oxygen, and increases in the growth of algae, in the receiving waters. Both effects are harmful to fish populations.

Coastal Ocean. The Coastal Ocean component of the L.A. Watershed project addressed a range of issues associated with coastal marine science, and linked coastal studies to other components of the overall watershed analysis. The primary focus in this area was the assessment of sources of pollution of the coastal waters of Santa Monica Bay, one of the largest and most economically important coastal assets in Southern California. Land and air sources were derived from those component analyses. Also studied was the movement of sedimentary DDT (although banned many years ago, these compounds are still prevalent in bay sediments). Pollutant contributions due to sewage outflows and industrial dumping were also considered. The work showed that an integrated analysis of coastal pollution leads to information that can be used to guide remediation plans for the region.

Summary. The L.A. Watershed study integrated the four major components of a coastal urban region: air, land, wetlands, and ocean. These components all play a role in the overall quality and supply of water. The interacting components affect levels of pollution within the entire system, and must all be considered when developing a plan for pollution control or remediation (Turco et al., 2002).

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APPENDICES

APPENDIX A. 1996 WATER AND WATERSHED GRANTS SUMMARY TABLE

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R82**4905**	Large Scale Disturbances and Small Scale Responses	Cole, C.A. -Penn State Cooperative Wetlands Center	• Wetlands • Restoration • Multi-Criteria Study	• Created wetlands in the restoration process did not meet standards of a "good", natural wetland.	• Course developed - "Introduction to Application of the HGM Functional Assessment Methodology", presented to environmental professionals. • General predictive model of hydrologic characteristics that allows assessment without long-term data collection. • Method for coring inland freshwater wetland soils. • Method for assessment of wetland probabilities based on broad geologic features.	• Surrounding landscape influences plant communities. • Created wetlands did not meet standards of "good," natural wetlands. • Biomass remained high in created wetlands, but soil organic matter did not increase, as it should, over time. • There is high mineral accretion in floodplains, impoundments, and depressions. • NWI measurements in Pennsylvania underestimate the occurrence of wetlands by nearly 100% within the Ridge and Valley Province.
-R82**5159**	Development and Application of Spectroscopic Probes for Measurement of Microbial Activity in Aquatic Ecosystems	Arnosti, C. - Univ. of North Carolina at Chapel Hill	• Microbial Activity • Scientific Techniques	• Product creates a faster method for analyzing the carbon cycling associated with microbial activity to be utilized in further research.	• A method of fluorescent labeling of macromolecules. • Methods to measure hydrolysis in natural systems. • Creation of new methods that aid in research on carbon cycling.	• Product creates a faster method and new analytical techniques for analyzing the microbial enzyme activities that help drive carbon cycling. These new methods will be utilized in further research. • Method can be used to follow the break down of a wide range of large molecules outside of the cell to better understand the rate at which small, easily degraded molecules can be provided to other organisms in the environment

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825284	Urban Stream Rehabilitation in the Pacific Northwest: Physical, Biological, and Social Considerations	Burges, S.J. -Univ. of Washington	• Restoration • Urban	• Provides a clear system to evaluate restoration plans. • Evaluates the effects of landscaping practices of streamside residents.	• Strategy for pursuing effective rehabilitation. • Evaluation methods for determining the effects of streamside resident landscaping practices. • Developing a set of products that provide guidance in the field of urban stream rehabilitation.	• Provides a clear system to evaluate restoration approaches. • Evaluates the effects of landscaping practices of streamside residents. • This research helps to evaluate prospective rehabilitation candidates and determining whether rehabilitation goals are realistic. • This data is easy to understand, and highly functional.
-R825285	An Integrated Approach to Assessing Water Management Options in a Major Watershed	Sabatier, P. - Univ. of California, Davis	• Economics • Harmful Toxins • Politics and Policies	• This study used two existing models to create a larger, up to date modeling system to determine the effects of management decisions. They worked with elected and appointed officials and decision makers to develop the model.	• A model that can aid in the prediction of the effects of management alternatives on hydrodynamic and water quality characteristics. • CALVIN model for economics for urban and agricultural water use with environmental use. http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/	• This study used several existing models to create a larger, up to date modeling system integrating hydrodynamics, water quality, fishery distribution, and economics to determine the effects of management decisions. • The investigators worked with elected and appointed officials and decision makers to develop the integrated sets of models. • Many elected and appointed officials were interviewed to better understand the political context for water decisions and how water decisions are made. • The Consumnes Research Group was created as an outgrowth of this study and focuses on monitoring and research needs within the Sacramento and San Joaquin River Watershed

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825286	Effectiveness of Regulatory Incentives for Sediment Pollution Prevention: Evaluation Through Policy Analysis and Biomonitoring	Reice, S. - Univ. of North Carolina at Chapel Hill	• Urban • Politics and Policies	• The results of this study aid managers in determining the most effective regulation plans for construction sites near water sources. This is in an effort to reduce sedimentation, which degrades water quality, and reduces aesthetic and economic value	• A chart displaying the effectiveness of various types of regulation and their effectiveness.	• The results of this study can guide managers in determining the most effective regulation plans for construction sites near water sources. This is in an effort to reduce sedimentation, which degrades water quality, and reduces aesthetic and economic value. • Many developers and enforcers contributed to this study to help determine the best, acceptable methods. • The frequency of the on-site inspections and the swiftness and severity of enforcement procedures are key concepts in regulation.
-R825289	Geochemical, Biological, and Economical Effects of Arsenic and other Oxyanions on a Mining Impacted Watershed	Miller, G. C. Univ. of Nevada, Reno	• Restoration • Economics • Toxins • Politics and Policies	• Mining sites that have been abandoned can produce poisons that enter the water system and travel down stream to agricultural and recreational areas	• Models of the concentration of poisons and transport were created as part of the study. • Surveys of local residents were conducted.	• Mining sites that have been abandoned can produce contaminants that enter the water system and travel downstream to agricultural and recreational areas • Numerous relationships formed between the investigators, EPA Region 9 personnel, and the regulatory and mining communities during this study, which will continue into the future because the issues in the project remain very important for mining impacted areas. • The topics of the two workshops held as part of the grant were very timely, but the interest and effort expended on these topics has increased since the grant ended. • One pit-lake has developed since completion of the grant and the conceptual model developed as part of the grant has been shown to accurately predict the amount of oxidation products that would be released into the pit-lake.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825290	Integrating Modeling and Management of Agriculturally-Impacted Watersheds, Issues of Spatial and Temporal Scale	Brezonik, P.L. Univ. of Minnesota	• Multi-Criteria Study • Agriculture • Economics • Politics and Policies	• Scientists tend to develop models that address cumulative effects at large scales while managers need to make localized decisions due to policy shifts.	• Computer models were created along with statistical evaluations of long-term stream, lake, and groundwater data. (Available from website: http://www.soils.umn.edu/ • Research/research5.htm) • An eight-step process to aid decision makers to identify, assess and implement restoration measures in agriculturally intensive watersheds was created. • Farmers were surveyed to explore the magnitude of transaction costs in the context of potential strategies to reduce agricultural pollution	• Scientists tend to develop models that address cumulative effects at large scales while managers need to make localized decisions due to policy shifts. Therefore, the smaller agroecoregions are a useful aid to watershed managers. • Targeting regions to reduce non-point pollution is cost effective. • Residents surveyed were willing to pay increased taxes and water bills to reduce levels of phosphorus pollution. • Watershed management in highly agricultural watersheds will be most effective when watersheds are complemented by agroecoregions to identify and target regions where specific combinations of BMPs for agricultural sediment and nutrient abatement are most suited.
-R825306	Watershed Protection in Agricultural Environments: Integrated social, Geomorphological, and Ecological Research to Support Ecosystem- based Stream Management	Rhoads, B. -Univ. Of Illinois	• Agriculture • Politics and Policies	• This plan integrates a study on the values of farmers and stakeholders in the area with geomorphological (stream channelization) data collected.	• Determined methods that impede and facilitate infusion of scientific knowledge to farmers. • Charts and diagrams available from study. • Results of interviews with farmers of the region to determine their concerns and opinions of scientific research and findings.	• This study integrates the values of farmers and stakeholders with geomorphological and ecological data (stream channelization). • The investigators determined the importance of linking scientific understanding with social factors motivating farmers to influence agricultural practices. • Educating farmers with scientific information must be done in a manner that recognizes the value system of farmers and how and why it varies from that of environmental scientists. • Meandering streams are better for fish abundance and biomass than straight channelized streams.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825335	Modeling Effects of Alternative Landscape Design and Management on Water Quality and Biodiversity in Midwest Agricultural Watersheds.	Santelmann, M.V. - Oregon State University	• Agriculture • Economics	• Evaluation of alternative futures of agricultural watersheds based on a process of involving a diverse array of disciplinary experts in design. •	• Species habitat association matrices for non-fish vertebrates, butterflies and plants. • Spatially Explicit Population Models (SEPMs) performed on amphibian response to changes. • SWAT – Soil and Water Assessment Tool • Information has been presented to state and local agencies (ex. Il EPA, Il DNR, Klamath tribe of Oregon) as well of plans for a project Web site.	• This study evaluated alternative futures of agricultural watersheds based on a process of involving a diverse array of disciplinary experts in the future landscape design. • Ecological and economic analyses of these small (5000-8000 ha) watersheds indicated that some changes in land use and agricultural practices result in environmental improvements and increased profitability of the enterprise.
-R825381	Integrated Urban Watershed Analysis: The Los Angeles Basin and Costal Environments	Turco, R. Univ. of California Los Angeles	• Wetlands • Multi-Criteria Study • Urban	• This study integrated the four major components of a coastal urban region: air, land, wetlands, and ocean; all playing a role in the overall quality and supply of water to an area. They interact and affect levels of pollution in the system.	• Graphics in final report of all steps in project including charts and diagrams suitable for use by decision makers. • Development of the regional oceanic modeling system. • Evaluation method of an urban watershed using main components of an ecosystem.	• This study integrated four major components of a coastal urban region: air, land, wetlands, and ocean; all play a role in the overall quality and supply of water to an area. They interact and affect levels of pollution in the system. • There are different types of indicators available and different methods of evaluation of watershed components and relationships, including differences in spatial measurements and watershed components. •

APPENDIX B. 1996 WATER AND WATERSHED GRANTS COMMON THEMES CHART

	Wetlands	**Restoration**	**Multi-Criteria Study**	**Microbial Activity**	**Urban**	**Agriculture**	**Economics**	**Harmful Toxins**	**Politics And Policies**	**Scientific Techniques**
R824**905**	X	X	X							
R825**159**				X						X
R825**284**		X			X					
R825**285**							X	X	X	
R825**286**					X				X	
R825**289**		X					X	X	X	
R825**290**			X			X	X		X	
R825**306**						X			X	
R825**335**						X	X			
R825**381**	X		X		X					

APPENDIX C. 1996 WATER AND WATERSHED GRANTS COMMON THEMES

Wetlands:

R824905- **Large Scale Disturbances and Small Scale Responses-** Cole C.A.
Success of created wetlands contingent on location.

R825381- **Integrated Urban Watershed Analysis: the Los Angeles Basin and Coastal Environments-** Turco, R.
Wetlands component characterizes the flora and fauna of the urban salt marsh and estuarine environments, as well as the responses of organisms and ecosystems to various stresses.

Restoration:

R824905- **Large Scale Disturbances and Small Scale Responses-** Cole C.A.
Preliminary evidence shows that landscape position, in addition to construction technique, is a prime determinant of function in created wetlands

R825284- **Urban Stream Rehabilitation in the Pacific Northwest- Physical, Biological and Social Considerations** – Burges, S.J.
Evaluates the degree to which rehabilitation efforts can recover lost functions, and determines the greatest impediments to successful rehabilitation in the urban environment.

R825289- **Geochemical, Biological, and Economical Effects of Arsenic and other Oxyanions on a Mining Impacted Watershed-** Miller, G.C.
Investigating the long-term chemistry and environmental risk of large pit lakes that will form after the mines close, long-term drainage from cyanidization heaps, biological effects of arsenic, and economic effects of long-term alteration of the watershed.

Multi-Criteria/ Multi Disciplinary Study:

R824905- **Large Scale Disturbances and Small Scale Responses-** Cole C.A.
Wetlands in the Landscape, Hydrology, Soils and Sedimentation, Macroinvertebrates, Biomass, PCMs, Cesium^{137} and A Method for Coring Inland, Freshwater Wetland Soils, and Historical Wetland Vegetation Community Response to Disturbance

R825290- **Integrating Modeling and Management of Agriculturally Impacted Watersheds, Issues of Spatial and Temporal Scale.**- Brezonik, P.L.
Bio-physical and social-economic variables interact in agricultural watersheds of varying scales, landscape conditions, and land-use management practices to affect export of nutrients and their effects on in-stream biological communities.

R825381- **Integrated Urban Watershed Analysis: the Los Angeles Basin and Coastal Environments-** Turco, R.
Regional meteorology and climatology; basin hydrology, vegetation and land use; anthropogenic water consumption and disposition; runoff sources of sediments, toxics and nutrients; air pollutant transport, transformation and surface deposition; downstream wetlands ecology and impacts; and coastal water circulation, biogeochemistry and sediments

Microbial Activity:

R825159- **Development of Application of Spectroscopic Proves for Measurement of Microbial Activity in Aquatic Ecosystems**- Arnosti, C.
spectroscopic probes that can be used to measure extracellular enzymatic hydrolysis rates of organic macromolecules in the water column and sediments

Urban:

R825284- **Urban Stream Rehabilitation in the Pacific Northwest- Physical, Biological and Social Considerations** – Burges, S.J.
The consequences of urban watershed alteration on physical and biological channel functions, evaluate the degree to which rehabilitation efforts can recover lost functions, determine the most successful types of such rehabilitation methods in the urban environment, and test the range of public visual acceptance for rehabilitation

R825381- **Integrated Urban Watershed Analysis: the Los Angeles Basin and Coastal Environments-** Turco, R.
The processes that control water availability and quality in a major urban watershed-the Los Angeles basin in Southern California. Including: regional meteorology and climatology; basin hydrology, vegetation and land use; anthropogenic water consumption and disposition; runoff sources of sediments, toxics and nutrients; air pollutant transport, transformation and surface deposition; downstream wetlands ecology and impacts; and coastal water circulation, biogeochemistry and sediments

R825286- **Effectiveness of Regulatory Incentives for Sediment Pollution Prevention: Evaluation Through Policy Analysis and Biomonitoring**- Reice, S.
Determine the effectiveness of different environmental policies, regulations and incentives in reducing the ecological risks and consequences of sedimentation to streams to create more effective management strategies to provide environmentally sustainable social and economic development in our watersheds.

Agriculture:

R8285290- **Integrating Modeling and Management of Agriculturally Impacted Watersheds, Issues of Spatial and Temporal Scale.**- Brezonik, P.L.
Bio-physical and social-economic variables interact in agricultural watersheds of varying scales, landscape conditions, and land-use management practices to affect export of nutrients and their effects on in-stream biological communities. Evaluating the usefulness of agroecoregions (landscape units roughly comparable in size to major watersheds) in understanding and managing nutrient pollution in large, agricultural drainage basins.

R825306- **Watershed Protection in Agricultural Environments: Integrated social, Geomorphological, and Ecological Research to Support Ecosystem-based Stream Management. -** Rhoads, Bruce L.
The research will provide an improved scientific basis for stream-management strategies that enhance and protect the ecological integrity of agricultural streams, and also reveal the points of penetration for infusing this scientific knowledge into the social mechanisms by which empowered local stakeholders structure and restructure watersheds.

R825335- **Modeling Effects of Alternative Landscape Design and Management of Water Quality and Biodiversity in Midwest Agricultural Watersheds**- Santelmann, M.V.
Integration the following components into a watershed-level assessment of ecological and human resources: 1) development and evaluation of alternative future land-use scenarios for agricultural watersheds, farm planning; 2) modeling of biodiversity (aquatic organisms, terrestrial vertebrates, wetland plants); and 3) development of water quality models for watersheds, modeling of water quality.

Economics:

R825285- **An Integrated Approach to Assessing Water Management Options in a Major Watershed**- Sabatier, P.

A model of California's statewide water system, including its surface water and groundwater sources, storage and conveyance facilities, and agricultural, environmental, and urban water uses. The model seeks to optimize economic returns from urban and agricultural water uses, subject to physical and policy constraints and focuses on the relationship between water diversions, crop mix, pesticide usage, and economic returns in a spatially explicit (GIS-based) model.

R825289- **Geochemical, Biological, and Economical Effects of Arsenic and other Oxyanions on a Mining Impacted Watershed-** Miller, G.C.

Examined the human behaviors and values for water flow changes accompanying the mine dewatering analyze recreational use on the main downstream reservoir on the river and its relationship to flows and water quantity using existing data. Miller et al. (2001) also analyzed this same recreational use and it relationship to agricultural uses downstream using a programming approach. Finally, the willingness to pay that Basin residents have to maintain "dewatering" flows or, failing that, to enhance recreation opportunities at the resulting pit lakes also were estimated.

R8285290- **Integrating Modeling and Management of Agriculturally Impacted Watersheds, Issues of Spatial and Temporal Scale.**- Brezonik, P.L.

Improve understanding of how bio-physical and social-economic variables interact in agricultural watersheds of varying scales, landscape conditions, and land-use management practices to affect export of nutrients and their effects on in-stream biological communities, and in turn to assess the role of knowledge about those effects in decision-making processes affecting local level land use.

R825335- **Modeling Effects of Alternative Landscape Design and Management of Water Quality and Biodiversity in Midwest Agricultural Watersheds**- Santelmann, M.V.

Ecological and socioeconomic impact of human land use and management decisions will be analyzed for six agricultural watersheds in Iowa, comparing the present landscape and three designed alternative visions of these same watersheds 25 years in the future. Explore how human attitudes and practical and economic constraints are translated into land-use and management decisions, and the spatial implications of these decisions at the watershed level.

Harmful Toxins:

R825285- **An Integrated Approach to Assessing Water Management Options in a Major Watershed**- Sabatier, P.

Work on mercury loadings, sources, and a flow begun at Clear Lake has now been expanded to the entire Sacramento watershed with the assistance of CALFED grants.

R825289- **Geochemical, Biological, and Economical Effects of Arsenic and other Oxyanions on a Mining Impacted Watershed-** Miller, G.C.

Arsenic and other contaminants are released during normal mining practices when mineralized rock is crushed and exposed to oxygen and water. Pit wall rock, waste rock dumps and spent heaps are all potential sources of As. In addition, many of the large pits created in this watershed penetrate groundwater and, when mining and the associated dewatering activities are discontinued, will result in large lakes as the groundwater tables begin to recover.

Politics and Policies:

R825285- **An Integrated Approach to Assessing Water Management Options in a Major Watershed**- Sabatier, P.

Explore the impacts of a variety of politically-significant policy scenarios and the reaction of important constituencies to those impacts. The implications of large-scale mechanistic models for long-term system management also will be explored.

R825286- **Effectiveness of Regulatory Incentives for Sediment Pollution Prevention:**

Evaluation Through Policy Analysis and Biomonitoring- Reice, S.
Integrate the social and regulatory theory behind sediment ordinances and policies and the resultant ecological impacts of sedimentation on the rivers and streams. It will identify what policies and regulations really work to enhance stream biota and ecosystem health and determine the effectiveness of different environmental policies, regulations and incentives in reducing the ecological risks and consequences of sedimentation to streams.

R825289- **Geochemical, Biological, and Economical Effects of Arsenic and other Oxyanions on a Mining Impacted Watershed-** Miller, G.C.
Examined the human behaviors and values for water flow changes accompanying the mine dewatering analyze recreational use on the main downstream reservoir on the river and its relationship to flows and water quantity using existing data. Miller et al. (2001) also analyzed this same recreational use and it relationship to agricultural uses downstream using a programming approach. Finally, the willingness to pay that Basin residents have to maintain "dewatering" flows or, failing that, to enhance recreation opportunities at the resulting pit lakes also were estimated

R8285290- **Integrating Modeling and Management of Agriculturally Impacted Watersheds, Issues of Spatial and Temporal Scale.**- Brezonik, P.L.
Many managerial frameworks and strategies have been proposed for managing and/or maintaining watershed resources. Nonpoint source pollutants are of concern in highly agricultural areas, and watershed management in these areas provides unique opportunities and challenges. The MRB provided a case study with which to demonstrate the consequences of management decisions in a large, highly agricultural watershed. Brezonik et al. (2001) developed an eight-step process to aid decisionmakers to identify, assess, and implement restoration measures in agriculturally intensive watersheds.

R825306- **Watershed Protection in Agricultural Environments: Integrated social, Geomorphological, and Ecological Research to Support Ecosystem-based Stream Management. -** Rhoads, Bruce L.
The social dynamics of community-based watershed projects to find points of penetration for infusing scientific knowledge that informs ecosystem-based stream management into the social mechanisms by which empowered local stakeholders structure and restructure watersheds.

Scientific Techniques:

R825159- **Development and Application of Spectroscopic Probes for Measurement of Microbial Activity in Aquatic Ecosystems. -** Arnosti, C.
Develop a new generation of sensitive and versatile spectroscopic probes that can be used to measure extracellular enzymatic hydrolysis rates of organic macromolecules in the water column and sediments. Based on efficient intramolecular energy transfer between donor and acceptor groups covalently attached to single macromolecules, so hydrolysis rates can be measured using simple fluorescence techniques