Compendium of the Results of the 1997 STAR Water and Watershed Grants

Submitted to

U.S. Environmental Protection Agency
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December 5, 2003

FOREWORD

This report was prepared by Perot Systems Government Services (formerly Technology Planning and Management Corporation), for the U.S. Environmental Protection Agency, National Center for Environmental Research, Science to Achieve Results Program. PSGS 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:

Ghiloni, J.A., E.A. Merritt, E.S. Walbeck, J.F. Campbell, M.G. Holland. 2003. Synthesis of the 1997 STAR Water and Watershed Grants. Prepared by Perot Systems Government Services (Formerly 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 1997 STAR Water and Watershed Grants and produce a document that outlines the results, products produced, and user communities for each of the 1997 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 1997 Water and Watershed EPA STAR Grants were reviewed in detail to determine how results of this research can or are being used by other researchers and decision-makers. Products useful to decision-makers resulting from the 10 grants include:

- Fourteen models;
- Six methods, strategies, processes, or practices;
- A comprehensive GIS database and a series of geospatial maps;
- Results of numerous stakeholder surveys and workshops;
- Three interactive web-based assessment tools;
- Numerous outreach materials including one community Outreach Task Force and a School Partnership Program; and
- Five frameworks for identifying various aspects of stakeholder concerns and environmental impacts.

Additionally, a new index to measure estuarine biotic integrity (EBI) was developed for use in future research. Each of the ten grants fell into one or more of the following categories/themes (See Appendix B):

- Restoration,
- Urban Conditions,
- Agricultural Conditions,
- Economics,
- Politics and Policies,
- Scientific Techniques, 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 R825751

Effects of Natural and Anthropogenic Processes on Tillamook Bay and Its Watershed: An Integrated Process Study and Land-Use Perspective.

Principal Investigator: James McManus, Oregon State University, College of Ocean and Atmospheric Science

Successes and Lessons Learned:

- *Research helped evaluate the role of ocean processes in estuarine systems.*
- *Research findings brought about a better understanding of the role of man-made and natural influences on water quality in Tillamook Bay.*
- *Transport paths and accumulation patterns of sediments were successfully established within Tillamook Bay.*
- *Investigators developed a better understanding of the impacts of timber harvesting (the removal of trees for lumber), agriculture, and salvage logging (the selected removal of trees susceptible to fire, insect attach, or disease) on in-stream conditions in the Tillamook and Kilchis sub-basins.*

Products:

- *A salmon cycle learning game for school children.*
- *Outreach materials including media presentation and video programming.*
- *Tillamook County Performance Partnership Outreach Task Force to improve the exchange of information between scientists and local citizens.*

User Community:

- *Policy and Decision-makers*

Themes:

Politics and Policies, Multi-criteria Studies

Research performed under this grant focused on examining the relative influences of different watershed activities on processes occurring within Oregon's Tillamook Bay (McManus et al., 2003). Of specific interest to investigators were the effects of various land-use practices on the physical, chemical, and biological condition of the Tillamook Bay watershed and the five major rivers that drain into it. To assess these effects, a series of hypotheses were developed and tested based on the following four issues:

1. Have land-use practices significantly altered the sedimentary budget of the watershed?
2. Are carbon, nutrient, and trace metal cycles significantly different among the five major river systems feeding the Tillamook estuary because of different land-use practices?
3. Have differences in land-use management practices between the Tillamook and Kilchis sub-basins of the Tillamook Bay watershed led to differences in the aquatic ecosystem health and biotic integrity in the riverine and stream environments in these sub-basins?
4. Are there differences between local knowledge and scientific observation, and, if so, why? Can actions to clarify knowledge contexts resolve differences? (McManus et al., 2003)

By developing a better understanding of these issues investigators hoped to provide the tools and information necessary to help foster a positive stewardship ethic among citizens and visitors to Tillamook County, as well as encourage the interaction and partnership of scientists and local community members.

Addressing the first issue, investigators conducted sediment transport and sediment composition analyses to uncover the history of sedimentation within Tillamook Bay and develop a better understanding of the

sedimentary budget of the watershed. Using surface samples, investigators could not distinguish the sediments coming from each distinct river basin but were able to distinguish those sediments derived from the Bay's marine beach source from those sediments derived from the combined river sources. As a result sediment transport paths and accumulation patterns were established for the Bay.

Due to the influence of logging and a series of forest fires at the beginning of the 20th century, investigators expected that core samples would show greater sediment inputs from the rivers than from the ocean beach. However, beach sand derived from decades of natural events such as subduction earthquakes, tsunamis, and storms dominated these samples. Investigators concluded that natural processes have a greater influence than human activities in the river watersheds on both sediment transport and Bay shoaling.

The second issue involved seasonal and monthly sampling of various nutrients and select trace metals within the five major rivers, as they entered and exited the estuary. The system's response to loading from urban and agricultural runoff was also assessed. Investigators concluded that further research of these elements and the estuary's response to them would have to be conducted in order to better understand how different land-use practices, namely urban and agricultural activities, might impact the geochemical budget of these elements within the watershed.

Investigation into the influences of land-use practice on in-stream condition (*issue three*) analyzed the impacts of varying human activities and differences in geologic make-up on conditions in the sub-basins of the Tillamook and Kilchis Rivers. The dominant land-use activities in the Tillamook sub-basin have included dairy farming and timber harvesting (the removal of trees for lumber) while salvage logging (the selected removal of trees susceptible to fire, insect attack, or disease) has been the dominant activity within the Kilchis. For each of these sub-basins, field data were collected on physical habitat, water quality, fish species composition, bottom dwelling macroinvertebrates, and algal communities. Investigations based on algal communities, as well as the volume of in-stream large woody debris found no correlation between land use and in-stream conditions in these areas. However, these results were only based on the impacts associated with timber harvesting.

Additional research into in-stream condition focused on the native fish species within these two river systems. There was sufficient predictive information for cutthroat trout and the major species of sculpin to determine that factors outside of land use appear to influence the abundance of these species. However, investigations into bottom dwelling macroinvertebrate communities did provide evidence to suggest that in-stream condition was impacted by both land use and geology (McManus et al., 2003).

Research into the fourth issue, differences between scientific information and local knowledge, showed that in general, local citizens were not aware of scientific finding about ocean processes, water quality, and riparian habitat (a natural strip of land bordering a stream) (McManus et al., 2003). In addition, local people showed little interest and tended to distrust the findings of non-local experts whose views did not match their own day-to-day experiences. To encourage the local community to become interested in the scientific knowledge an outreach organization, the Tillamook County Performance Partnership Outreach Task Force, was formed.

Estuaries have been recognized as one of the most important environments in the coastal zone (McManus et al., 2003). Both the natural and human-induced processes occurring within a watershed system can have a significant impact on the overall health of an estuary. Understanding these processes—and the extent to which the general public understands the relationships between them—plays a critical role in the development of sound management practices in both environments.

2.2 STAR Grant R825757

Social and Ecological Transferability of Integrated Ecological Assessment Models

Principal Investigators: Linda Deegan, Marine Biological Laboratory, Ecosystems Center

Successes and Lessons Learned:

- *Ecosystem modeling is an accurate method of predicting ecosystem responses to land use and land-use change.*
- *Models are a cost effective way to gain competent data about existing and likely future land uses.*
- *The utility of policy models is often hindered by their complexity.*
- *To improve watershed management through the use of models in local decision-making, partnerships must be made between modelers and users so they may reflect the more immediate interests and needs of local citizens and managers.*
- *Models have the potential to be misused as users may misinterpret results or use the models strategically to support preconceived agendas. Models can also be distorted by the personal values and policy judgments of the developer.*

Products:

- *A tutorial website designed to teach users the impacts of land use on water quality and living resources in the coastal estuaries of southern New England (http://ecosystems.mbl.edu/Research/Clue/).*
- *CLUE (Changing Land Use and Estuaries) ecosystem response model.*
- *An Index of Estuarine Biotic Integrity (EBI).*
- *Two new survey instruments to investigate perceptions regarding the utility and applicability of nitrogen-loading models as decision-making aids.*

User Community:

- *Policy and Decision-makers*

Themes:

Politics and Policies, Scientific Technique, Restoration

Increased nitrogen loading to estuaries has been strongly correlated to eutrophic conditions, habitat loss, and decreased species diversity and abundance within these systems. This grant investigates excess nitrogen loading as it relates to various land-use practices in estuaries located in southeastern New England. In this area, excess nitrogen has been linked to the degradation and loss of eelgrass habitat, an event closely associated with decreases in fish diversity and abundance. The focus of this research was the creation of a general, dynamic, and predictive estuarine ecosystem response model—CLUE (Changing Land-use and Estuaries)—to determine how water and habitat quality might respond to various nitrogen-loading scenarios and land-use management decisions. CLUE is different from many comparable models in that it helps decision-makers take into consideration the concerns of local citizens.

The CLUE model was designed to run in concert with an existing nitrogen-loading model (e.g., the nitrogen-loading model NLOAD or the nutrient-loading model NLM) and uses ecological parameters based on basic physical and biological data that are readily available to local managers (e.g., published USGS charts, state GIS archives). A unique aspect of the CLUE model is that it assesses estuarine condition in terms of eelgrass habitat quality and quantity, two factors that have been strongly associated with nitrogen loading and eutrophication in estuaries. This model can estimate the amount of area suitable for eelgrass growth under pristine and degraded light conditions. In addition, as the relationships between eelgrass density and fish abundance and diversity have been incorporated into the model, the effects of nitrogen loading on these important ecosystem properties can be predicted (Deegan et al., 2001).

Extensive testing of the CLUE model in Waquoit Bay and in a range of shallow coastal sites across Massachusetts, Rhode Island, and Connecticut showed that it has the ability to simulate reasonably well the overall patterns of ecologically important variables related to eutrophication (Deegan et al., 2001).

The second research objective sought to better quantify the effects of eelgrass habitat loss on estuarine fish communities by assessing measures of biotic integrity (the ability of an organism to function successfully within a given natural habitat). Investigators developed and applied an index of Estuarine Biotic Integrity (EBI) to various estuarine sites across Massachusetts, Rhode Island, and Connecticut. Each site was classified as either low or medium quality by density and biomass of submerged rooted vegetation (Deegan et al., 2001). The EBI applied to these sites was composed of eight metrics that measure important characteristics of fish assemblages including:

- Numerical abundance
- Biomass
- Total species
- Species dominance
- Species composition by life history and activity zone
- Individual species health

Results of the tests showed that the EBI was successful in classifying habitat quality (Deegan et al., 2001).

Researchers also tested the transferability of the EBI to areas outside of New England by applying the index to several sub-estuaries along the southwestern shore of the Chesapeake Bay. Although some adjustments needed to be made to account for differences in the fish community structure and habitat use, the EBI was also successful in classifying habitat quality at these sites. Not only is the EBI a useful measure of ecosystem function and restoration effectiveness, it also provides a summation of fish community characteristics that are sensitive to habitat function and integrity, which may be applied to future applications of the CLUE model (Deegan et al., 2001).

The final component of research attempted to assess the ability of planners to use models to make scientifically sound management decisions regarding land-use practices. Investigators surveyed over 150 local government officials throughout southeastern Massachusetts to uncover perceptions regarding the utility and applicability of nitrogen-loading models as tools in decision-making. Investigators were also able to study a pre-existing model, known as the MANAGE model, to study the way that local board members used the model as a decision-making aid (Deegan et al., 2001).

Investigators found no evidence to support the idea that local government board members would be interested in using an ecosystem or nitrogen-loading model as an aid to decision-making (Deegan et al., 2001). Investigators hypothesized that this was primarily because present models are only capable of informing local decision-makers on land-use impacts at large scales (e.g., zoning districts or large sub-divisions) rather than on smaller, more immediate scales (e.g., individual building lots). In addition, people tended to view models as too complicated for the lay user.

Results from this research show that models have the ability to provide critical information regarding ecosystem health and have the potential to play a valuable role in the making of sound, scientifically based management decisions. Efforts towards decreasing model complexity and increasing communications between modelers and potential users should continue to ensure future models better serve both community and watershed management goals.

2.3 STAR Grant R825758

Community Values and the Long-term Ecological Integrity of Rapidly Urbanizing Watersheds

Principal Investigators: M. Bruce Beck, University of Georgia, Warnell School of Forest Resources

Successes and Lessons Learned:

- *Using the concept of adapted community learning, researchers discovered that stakeholders are more concerned about the longer-term than the shorter-term well being of Lake Lanier.*
- *Developed a concept of environmental decision-making that would enable science-based models to be responsive to both the short- and long-term community values.*
- *Improved the understanding of ecosystem behavior within Lake Lanier and identified key elements of the current state of the lake and its future inputs.*
- *Conducted a "Foresight Workshop" to help stakeholders and decision-makers plan for the future of Lake Lanier.*
- *Stakeholders' greatest concern for Lake Lanier was public health, not ecological integrity.*
- *Based on research and model results, the optimistic views on the future of Lake Lanier are close to three times more likely to occur than the pessimistic outlooks on the future.*
- *Successfully remedied two prior limitations of Regionalized Sensitivity Analysis (RSA) by adjoining a Tree-Structured Destiny Estimation (TSDE) procedure to assess multivariate features by circumventing small-sample size problems, using a Uniform Covering with Probabilistic Rejection (UCPR) algorithm.*

Products:

- *A framework for adaptive community learning to identify stakeholder concerns and develop target outcomes for the future of Lake Lanier.*
- *A model of Lake Lanier that incorporates new data on the microbial food web and sediment biochemistry of the Lake.*

User Community:

- *Policy and Decision-makers*
  - "Vulnerability of water quality in intensively developing watersheds" was presented to the Environmental Protection Division, Georgia Department of Natural Resources.
  - "Incorporating stakeholder concerns into a lake ecosystem model…." was presented to the North American Lake Management Society.
  - "Integration of stakeholder values and scientific models in management strategies" was presented at the National Conference on Environmental Decision-Making.
  - "Phosphorus cycling in southeastern Piedmont Lakes:…" was presented to the Georgia Water Resources Conference.
- *Stakeholders*

Themes:

Urban, Politics and Policies, Multi-criteria Studies

The research conducted under this grant focused on the development of a model to explore different approaches to maintaining the integrity of an environmental system based on short- and long-term community values. The study area for this investigation was Lake Lanier in Georgia. This lake supports the surrounding communities in terms of hydroelectric power generation, water supply, flood protection, and recreation. The research conducted in this area seeks to integrate ecological, hydrological, and social/policy sciences in the rapidly urbanizing watershed of Lake Lanier where the preservation of long-term ecological integrity is perceived as being at stake (Beck et al., 2002). Through this study, researchers hope to develop a concept of environmental decision-making that brings both science and community values into play for both the short- and long-term. In addition, researchers also hope to achieve a greater understanding of the basic aspects of the ecosystem behavior of the lake.

Researchers facilitated adaptive community learning by working with small groups of stakeholders. Adaptive community learning takes into consideration the actions and processes of decision-making, whereby the community of stakeholders experiences learning about itself, its relationships with the valued piece of the environment, and the functioning of the physical environment (Beck et al., 2002). To facilitate this process stakeholder concerns about the long-term future of Lake Lanier were gathered using a survey questionnaire and a workshop session. These concerns and the opinions of stakeholders were then used to develop target outcomes for the future and a scientific model for Lake Lanier. The scientific model was developed in previous studies; however, new material for the description of the microbial food web and sediment biochemistry found during this study were incorporated.

Results from this portion of the study found that stakeholders' concerns were focused on the long-term well being (20 to 30 years) of Lake Lanier. Their primary concerns were bacteria (pathogens) in the lake water and the safety of the water for swimming (Beck et al., 2002).

Research under this grant also studied the ecosystem of Lake Lanier. The method of Regionalized Sensitivity Analysis (RSA) was used to help identify and assess key elements of the current state of the lake and its future inputs in terms of both the impacts associated with local policy changes and other (essentially) uncontrollable disturbances (Beck et al., 2003). In direct response to the identified concerns of stakeholders, researchers studied the effects of fertilizer within the watershed, particularly how fast the iron-rich soil of the area absorbs phosphorus. Also studied was the presence and propagation of E. *coli* bacteria in the area. Understanding these processes will help planners and managers address the long-term concerns about the Lake's future.

This study has used the concerns and opinions of the stakeholders local to Lake Lanier and its watershed to help direct the future of their management strategies. By integrating what the stakeholders are saying, the scientists in the project are exemplifying their goal of environmental decision-making in which science-based models are responsive to identified community values. The decision-making and the values evolve together to accomplish both short and long-term goals.

2.4 STAR Grant R825759

Risk Based Urban Watershed Management-Integration of Water Quality and Flood Control Objectives

Principal Investigator: Vladimir Novotny, Marquette University, Milwaukee, (WI) (currently Northeastern University, Boston)

Successes and Lessons Learned:

- *Urbanization has negative impacts on fish community structure and macroinvertebrate health.*
- *Analyses indicate that lead presents the highest ecological risk to waterbodies.*
- *Variables, such as income and education, as well as location within the flood plain, have little effect on local citizens' willingness to pay for management projects.*
- *Research helped in the advancement of the risk-based approach to water quality management.*
- *The pollution-loading model developed, can assist TMDL programs and studies by providing a tool to assess the effect of pollution on the integrity of the receiving waterbodies.*
- *As a result of this grant work, the Institute of Urban Environmental Risk Management has become the center of environmental research at Marquette University.*

Products:

- *Foundation of the Institute of Urban Environmental Risk Management at Marquette University.*
- *Methodology for evaluating risk due to flooding supported by a GIS-based application.*
- *An improved methodology for assessing ecological risk due to water column contamination.*
- *A GIS-based urban watershed pollutant-loading model.*

User Community:

- *Regional, State, and Federal Planners and Decision-makers (Two half-day workshops were held to present goals, methodologies, and major results.)*
  - Southeastern Wisconsin Regional Planning Commission
  - Wisconsin Department of Natural Resources
- *Local Stakeholders (Two half-day workshops were held to present goals, methodologies, and major results.)*
  - Metropolitan Milwaukee Sewage District
  - Mayors of suburban communities
  - Municipal drainage departments
  - Environmental consultants
  - Environmental advocacy organizations
- *The U.S. Environmental Protection Agency*
  - Office of Water
  - Region 1
- *International Environmental Scientists in Japan*
- *Colleges and Environmental Research Groups*

Themes:

Urban, Economics, Politics and Policies, Multi-criteria Studies

This study attempted to identify and quantify the potential risks to human, biological, and environmental health due to contamination from urban and suburban watershed development. The focus of this research was on creating mathematical formulas that could assess the risk involved with different management methods in the urbanized watersheds. The project examined urban waterbodies along two related but often conflicting dimensions:

- The degree to which urban development influences flood risks.

- The degree to which it influences the ecology of the water bodies (Novotny et al., 2002).

A methodology for assessing flood control, as well as cost models for urban watershed management were developed to optimize both flood control methods and the integrity of the water entering the system. These research efforts help to develop a bigger picture of the risks, both financially and environmentally, associated with different watershed management styles. In addition, findings regarding the effects of urbanization will be useful in the development of watershed management plans for different watershed systems and can help decision-makers and planners choose the best plans to reduce the impacts associated with urbanization.

Research on this project was conducted in Milwaukee, Wisconsin in two different watersheds: the Oak Creek watershed and the Menomonee watershed. To analyze the effects of urban development on the living organisms an index of biotic integrity was applied to these sites. An index of biotic integrity analyzes the overall health of the organisms that live within the system. In this study researchers focused on fish species composition and macroinvertebrates. Within the study watersheds, a high percentage of species tolerant to urbanization but reflecting low species diversity indicated poor stream quality (Novotny et al., 2003b). In addition, these sites did not support fish communities typical for this region (Novotny et al., 2003b). Macroinvertebrate studies also showed significant impairment due to urbanization (Novotny et al., 2003b).

Changes in the floodplain due to urbanization were also studied. Researchers used a computer program to predict the changes in a flood plain over time to assess the increase in the risk of flooding as watersheds are urbanized.

The second part of this project was based on the financial feasibility of different types of management plans. This portion of the study assessed the willingness of residents in the area to pay for various watershed management projects. Phone surveys were conducted and participants were asked questions to help researchers distinguish among the following scenarios:

- The willingness of residents to pay for flood control.
- The willingness of residents to pay for ecological restoration of the urbanized watersheds.
- The willingness of residents to pay for a plan that includes both of these aspects (flood control and ecological restoration).

The survey on the benefits of flood control projects only included residents in the Menomonee River watershed that is significantly more urbanized and anticipated flooding in the last ten years. Focus group sessions that preceded the survey revealed that citizens in the less urban Oak Creek watershed had very low preference for flood control projects. However, survey participants in both watersheds did indicate that they would pay an average of 84 dollars for a watershed plan regardless of what the management plan would accomplish. Participants also indicated that they were willing to pay more if they felt they were doing something beneficial for their community and environment.

Research conducted under this grant helps to analyze the changes in the environment, particularly the floodplain, due to urbanization. The risks and financial aspects associated with different management plans were evaluated and plans incorporating flood prevention and ecological health strategies were assessed. Lastly, the willingness of local residents to pay an increased fee on their taxes for the rehabilitation and watershed management of watershed areas was investigated. Based on these investigations, this study of quantitative risks of urbanization to the watershed ecosystem including people residing in the watershed and affected by the watershed will help to develop a methodology for watershed management in urban and urbanizing areas (Novotny et al., 2003a).

2.5 STAR Grant R825760

From Landscapes to Waterscapes: An Integrating Framework for Urbanizing Watersheds

Principal Investigator: Panayiotis Diplas, Virginia Polytechnic Institute and State University

Successes and Lessons Learned:

- *Impact to watershed hydrology increased as land conversion became more drastic.*
- *The presence and amount of pollutants in sampled fish species indicate that fish may be an excellent biomarker of environmental and water contamination, and may have the ability to serve as a warning system for human health hazards.*
- *Economic analyses reveal that both residents and local governments derive economic benefits from sprawling developments.*
- *Increased area of impervious surfaces due to urban development is the most significant indicator of hydrologic change.*
- *Hydrologic impacts associated with the expansion of existing communities have less impact on water flow and discharge than those associated with new community developments.*

Products:

- *A hydrologic modeling framework for assessing the impacts of alternative landscapes on surface and subsurface water flows.*
- *A new strategy for modeling flow patterns via channel topography and complexity.*
- *Three spatial hydraulic metrics to aid in locating and distinguishing biologically important features.*
- *Procedures for predicting the response of fish and macroinvertebrate communities to urbanization-induced changes to biological and hydrologic conditions.*
- *A conceptual model for predicting land prices based on characteristics of urban development and land use.*
- *A simulation model to predict water and sewer costs as a function of the spatial distribution of services.*
- *A computer simulation model to estimate the annualized cost of delivering water and sewer service to residential areas.*
- *A web-based model integrating the hydrological and economic aspects of this study.*
- *Proceedings of the "Integrated Decision-Making for Watershed Management" conference.*

User Community:

- *Policy and Decision-makers*
  - "Integrated Decision-Making for Watershed Management" conference took place in Chevy Chase Maryland. The awareness that was raised during this grant effort regarding watershed management issues and the need for multidisciplinary efforts to resolve them acted as a springboard for this conference. The conference proceedings were published in two Special Issues of the Journal of the American Water Resources Association.

Themes:

Urban, Politics and Policies, Economics, Multi-criteria Studies, Restoration

This study integrates hydrologic, ecological, and economic consequences of alternative landscape scenarios occurring during the urbanization process of a watershed system (Diplas et al., 2003a). The work conducted under this grant produced a set of linked models and incorporated them into a general methodology for holistic watershed assessment. The information used to develop these models and this methodology were derived from research conducted under this grant, as well as results from other related environmental assessments and watershed management practices. In addition, a case study was performed

in the Upper Roanoke River watershed in southwest Virginia to test the system of linked models. This study included a stakeholders' panel to ensure the relevancy of this management aid to actual community watershed management needs. Using this methodology in combination with these models, the goal of researchers was to help facilitate the development of policy likely to be effective in achieving social objectives by allowing evaluation of consequences during policy development and revision rather than after adoption and implementation (Diplas et al., 2003a).
Urbanization, farming, and other types of land-use activities can alter water flows and erosion rates within a watershed. These effects can lead to more frequent flooding and increased pollutant loading, which in turn can result in the degradation of the physical and biological integrity of streams and other aquatic wildlife (Diplas et al., 2003b). Working towards prevention or restoration of these effects costs resources (e.g., time and money) that many communities cannot afford. The central issue for most communities is creating a plan that ensures environmental quality and at the same time comes at an affordable price to residents. This study focused on addressing this need. Specifically, researchers sought to:

- Develop a hydrologic framework for assessing impacts of alternative landscapes on surface and subsurface waters;
- Develop procedures to predict the response of fish and larger invertebrates to urban-induced water quality changes;
- Assess the policies and economic decisions associated with alternative landscape scenarios and estimate the economic consequences of these scenarios on local governments.

Research groups were assigned to address each of the following four components:

- Hydrology/hydraulics;
- Biology;
- Economics/policy;
- Problem-solving environment.

Each research group used computer programs to either predict the effects of land-use change or to integrate the different information derived from the four study components. The hydrology/hydraulics group studied the effects on groundwater in the watershed with the change of land use and coordinated with the economics group to develop alternative land development scenarios. A simulation computer program was developed to help determine water flow in certain areas and analyze 'what if' scenarios of land-use change, using data from 1996-98. This group also studied the effects of different development scenarios on sediment transport, stream depth, and velocity change. The biology group studied the effects of urbanization by studying the fish and large invertebrates of the area. These data were compared with data from similar sites to produce a more holistic stream ecology assessment. The economics group determined the changes in land prices resulting from different settlement patterns and their effects on the tax base and tax revenue, and determined the costs of providing local public services based on different land settlement patterns. The problem-solving environment group developed a model using mapping and visual computer programs to create land settlement scenarios based on percentage of type of land use, the amount in acres of each land use, and the population density of the land use. This program has been formatted for remote use via the Internet.

The information compiled and researched under this grant has produced results that can help decision-makers establish the most environmentally sound land usage scenarios for watershed areas under the pressure of increased urbanization. The methodology developed can be used in a variety of situations as an aid to planning and decision-making in different communities experiencing different rates of growth.

2.6 STAR Grant R825761

An Integrated Ecological and Socio-Economic Approach to Evaluating and Reducing Agricultural Impacts on Upper Mississippi Watersheds

Principal Investigator: Prassanna Gowda, University of Minnesota

Successes and Lessons Learned:

- *Identified key factors that affect the adoption of conservation farming practices through the use of a socioeconomic study.*
- *The Agricultural Drainage and Pesticide Transport (ADAPT) model is not suitable for simulating condition in areas dominated by urban land use.*
- *Regional variations in landscape characteristics can have a strong effect on stream communities and, therefore, management plans may be more effectively approached from the watershed scale (Burgess, undated).*
- *Large-scale changes in agricultural land-use practices can affect the local biological integrity of streams even in highly disturbed basins (Haro et al., 2000).*
- *Farmers in the study watershed were actively seeking information about soil and water conservation practices. However, the production practices used by these farmers tended to offset the positive environmental effects of the conservation practices they were adopting.*
- *In the Lower Minnesota River watershed conservation tillage practices are adopted for reasons other than soil conservation.*
- *In both the Maquoketa River and Minnesota River watersheds, the existing rate of adoption of soil conservation tillage was strongly related to Benthic Macroinvertebrate Index of Biological Integrity (BM-IBI) scores (Gowda et al., 2002).*
- *Universal Soil Loss Equation (USLE) may serve as an important tool for designing watershed biomonitoring programs (Burgess et al., 1999).*

Products:

- *Model of the Lower Minnesota River watershed.*
- *A calibrated ADAPT model to predict flow, sediment, and nitrate loadings.*
- *A set of alternative agricultural management practices for the Lower Minnesota River watershed.*
- *A comprehensive GIS Database for the Lower Minnesota River and Maquoketa River watersheds.*

User Community:

- *Policy and Decision-makers*
  - The Minnesota Pollution Control agency is comparing the results of this project with similar work done by a contractor/consultant. In addition, results are being used for Total Maximum Daily Load (TMDL) development in other area watershed projects.
- *Academia*
  - The University of Minnesota Economics Department and the Minnesota State University are both using the GIS database developed by this project.

Themes:

Agriculture, Politics and Policies

Under this grant, investigators utilized various models to assess agricultural impacts to water quality and ecosystem heath in the Upper Mississippi River watershed. In addition, they evaluated the potential water quality benefits associated with implementing alternative land-use management strategies in watersheds of the Mississippi River Basin. The goal of this study was to produce findings that would be useful in the development of intervention programs that could facilitate the adoption of soil and water protection practices at the farm level (Gowda et al., 2003b). The study area focused on two watersheds of the Upper

Mississippi River Basin, the Lower Minnesota River watershed in eastern Minnesota, and the Maquoketa River watershed in northeastern Iowa. The Big Darby Creek watershed in central Ohio, facing similar land-use issues as the Upper Mississippi, was also used in the socioeconomic portion of this investigation.

Flow, sediment, and nitrogen loadings from the study watersheds were predicted using a spatial-process model in combination with the Agricultural Drainage and Pesticide Transport (ADAPT) water management model. This model consists of four components: hydrology, erosion, nutrient, and pesticide transport. The ADAPT model was calibrated and several parameters were modified to more accurately reflect local conditions. Model test simulations and statistical evaluations were conducted and compared to local observed water flow and water quality data. Results verified that the model was successful in simulating the quantity and quality of water flow in agriculturally dominated areas of the Lower Minnesota River; however, the model was not successful or well suited for simulating areas of urban land use.

As a result of this grant a comprehensive GIS database was also developed for the Lower Minnesota River and Maquoketa River watersheds. The database includes detailed land-cover maps that have the unique ability to identify specific crop types and farm types. These maps became the most recent available for this area. This database was used by investigators in the biological component of this study to identify potential sites for macroinvertebrate surveys and to evaluate the impacts of existing agricultural management practices on stream biology (Gowda et al., 2003b). Soil erosion potential was also estimated for key landscape features within the study watersheds. Results of these investigations showed that the condition of macroinvertebrate communities in both study areas increased with increased rates of soil permeability and conservation tillage. However, the percent of row crop agriculture had no apparent effect on community health (Gowda et al., 2003b). In addition to this study, this database has also been used by other researchers to develop point-nonpoint emission trading permits for the Minnesota River Basin (Johansson, 2000 as cited in Gowda et al., 2003b), as well as by the Minnesota Pollution Control Agency for Total Maximum Daily Load (TMDL) development in other area watershed projects.

The ecological component of this research sought to the assess:

- Relationships among landscape and stream habitat characteristics and benthic macroinvertebrate community composition in the two study watersheds;
- Relationships between tillage practices and the biological integrity of tributary streams in the Upper Mississippi River watershed; and
- Relationships between sediment erosion rates and local macroinvertebrate community structure within the two study watersheds.

(Burgess, undated; Haro et al., 2000; Burgess et al., 1999).

The Universal Soil Loss Equation (USLE) was used to derive Sediment Erosion Potential (SEP) to study stream habitat and landscape characteristics, as well as the impact of sediment erosion rates on macroinvertebrate community structure. In addition, a Benthic Macroinvertebrate Index of Biological Integrity (BM-IBI) was developed to assess macroinvertabrate health. Results of this research revealed that regional variations in landscape characteristics can have a strong effect on stream communities and, therefore, management plans may be more effectively approached from the watershed scale (Burgess, undated). Investigations related to BM-IBI scores also revealed that large-scale changes in agricultural land-use practices can affect the local biological integrity of streams even in highly disturbed basins (Haro et al., 2000).

An extensive socioeconomic study was also conducted in both of the study watersheds, as well as the Big Darby Creek Watershed in central Ohio. The study sought to identify and assess the social, technical, economic, farm structure, and institutional factors that affect the adoption of conservation production

systems among land-owner operations within the watersheds (Gowda et. al., 2003b). Based on results from the surveys, researchers identified a set of four alternative agricultural farming practices:

- Increased adoption of conservation tillage (a systems that leaves crop residue from harvesting such as leaves, stalks, and roots on the soil surface instead of plowing to reducing the effects of erosion from wind and water).
- Conversion of cropland to pasture land.
- Varying nitrogen fertilizer application rates.
- Increased subsurface tile drainage (a system that includes a buried perforated pipe designed to remove excess water from soils).

Each alternative practice was applied to the calibrated ADAPT model to evaluate the effects on water quality within the Lower Minnesota River watershed. While results of the model simulations showed that each alternative practice produced benefits to water quality, the adoption of nitrogen-fertilizer best management practices were found to be offset by increased nutrient loading from the adoption of other conservation practices (e.g., conservation tillage and subsurface tile drainage) and visa versa. Further research will be required to better understand the connection among agricultural management practices to achieve solutions that will best improve water quality.

Data collected in the socioeconomic surveys were also used to help assess the success and/or failures of past soil and water protection initiatives within the study watersheds (Gowda et al., 2000). In addition, the data were used to develop statistical models to predict the likelihood of specific soil and water conservation practices being adopted by farmers and to assess the potential agricultural productivity that could result from the adoption of these practices. Results of this portion of the investigation found that farmers in all of the study watersheds had adopted some soil and water conservation production practices; however, they continued to use production practices (e.g., conservation and conventional tillage, crop rotation, and nutrient management strategies) that could negate the positive environmental effects of the conservation practices employed at the time of data collection. (Gowda et al., 2003a). In addition, it was discovered that the extensive investments in conservation programs made in the Big Darby Creek watershed have resulted in few benefits in terms of changed conservation behaviors compared with farmers in other watersheds (Gowda et al., 2003).

2.7 STAR Grant R825762

Linking Watershed-Scale Indicators of Change in Atmospheric Deposition to Regional Response Patterns

Principal Investigator: Jeffery S. Kahl, University of Maine

Successes and Lessons Learned:

- *Declines in atmospheric deposition of sulfates have led to a decrease in sulfate concentrations in surface waters in Maine; however, the expected recovery of these watersheds from acidification has been minimal, and in some instances acidification has increased.*
- *The inability of Maine watersheds to recover from acidic conditions may be the result of decreases in concentrations of base cations (i.e., calcium and magnesium) in these waterbodies.*
- *The effects of climate change and climate variability may be influencing the acid-base chemistry of Maine watersheds in undetermined ways. These effects might even be counteracting the positive effects of decreased acid deposition.*
- *Atmospheric loading of nitrogen may be influencing the acid-base status of Maine watersheds in undetermined ways.*

Products:

- *Adapted the Tracking and Analysis Framework (TAF) to Maine watersheds.*

User Community:

- *Policy and Decision-makers*
  - The policy and decision-makers most interested in the research were the U.S. Environmental Protection Agency Office of Air and Radiation and ultimately, Congress, as described below. In addition, researchers have worked with the State of Maine Department of Environmental Protection Air Division, and the New England Governor's Eastern Canadian Premiers working group on acid rain.
- *Legislators*

Themes:

Politics and Policies

Research conducted under this grant investigated the response of surface waters to various levels of acidification and assessed their ability to recover. The goal of the research was to link scientific knowledge to the practical needs of decision-makers to produce results that could be applied to management and policy decisions made by industries and governments at the local, state, and federal level. Results of this research are expected to have a direct influence on future policy and legislation mandated under the Clean Air Act.

Researchers under this grant investigated surface water responses to "natural" acid deposition occurring in high elevation lakes in Maine and compared them to the responses to experimental acidification in the study watershed of Bear Brook Creek in eastern Maine. Results of the comparison showed that there has been no population-wide acid-base recovery in the high-elevation lakes, despite substantial declines in sulfate concentrations in precipitation (Kahl et al., 2002). In addition, reductions in ion concentration and acid neutralizing elements such as calcium have also declined, causing an increase in the vulnerability of these lakes to acidification.

Soils were also sampled in 20 of the high elevation lakes and in several Bear Brook Creek sites to determine their contribution to lake chemistry and the acid-base status of the lake waters. In the high elevation lakes, few strong correlations were evident between soil chemistries and lake chemistries (Kahl et al., 2002). However, at the Bear Brook Creek study site there was clear evidence of the long-term

additions of nitrogen and sulfur to the treated watershed when compared to the reference watershed for both cation chemistry (acid neutralizing chemistry) and nitrogen (Kahl et al., 2002).

Recovery responses of acidified water bodies were predicted using a calibrated version of the Tracking Analysis Framework (TAF) model that incorporates the biotic and socioeconomic effects of acid deposition (Kahl et al., 2003). This model was used in concert with a modified version of the Model of Acidification of Groundwater Catchments (MAGIC). Researchers compared the model results of potential future deposition scenarios in the high elevation lakes in Maine to responses in the Adirondack lakes in New York. Results showed that the predicted acid neutralizing capacity of these water bodies would increase over a 30-year period (2000 to 2030) under all deposition scenarios. The range of acid neutralizing capacity values produced by the models reflected ranges similar to those lakes that are currently in the process of recovery.

Based on the results of the research conducted under this grant, declines in atmospheric deposition of sulfate have led directly and rapidly to widespread declines in sulfate concentrations in Maine surface waters, similar to the response in the rest of the northeastern United States (Kahl et al., 2002). A response such as this is one indication of the success of the United States Clean Air Act and efforts by industry to reduce sulfate emissions (Kahl et al., 2002). However, the full recovery of these surface waters from acidic conditions is an issue that has not yet been resolved. The results of this research will play a key role in the assessment of future amendments to the Clean Air Act in determining their effectiveness in promoting the recovery of the nation's freshwater resources from acidification.

2.8 STAR Grant R825791

Ecological Risks, Stakeholder Values, and River Basins: Testing Management Alternatives for the Illinois River

Principal Investigator: Mark Meo, University of Oklahoma

Successes and Lessons Learned:

- *Disagreements exist over the magnitudes and causes of problems in the Illinois River, as well as over who is to blame and what should be done to solve these problems (Meo et al., 2003a).*
- *Stakeholders are most concerned and knowledgeable about problems and associated impacts that are visible, local, and have media attention—including alcohol consumption, inappropriate behavior by tourists, and littering (Meo et al., 2003a). Stakeholders, therefore, tend to consider management policies focused on preserving the aesthetic value of the River system to be of greater importance than policies for protecting public health and recreation.*
- *Policy-makers are most concerned with less visible, widespread, water quality-based problems and issues such as nutrient loading from over application of fertilizer, municipal waste, and riparian area protection (Meo et al., 2003a).*
- *Poultry farming and the impacts of septic systems were viewed to be the greatest threat to water quality in the Illinois River watershed.*
- *Agricultural areas were discovered to be the most significant contributors to phosphorus loading during runoff.*
- *Distrust between stakeholders and government officials—particularly the federal government—are high. Stakeholders have an overwhelming preference to participate directly in the policy making process as opposed to deferring to government discretion (Meo et al., 2003a).*
- *Stakeholders prefer coercive policies regarding enforcement of existing laws and regulations, such as apply to point source discharge and civil law regarding behavior. Stakeholders also prefer educational and voluntary strategies with compensation for economic losses from management of less regulated activities (e.g., farming and rural/suburban land use) (Meo et al., 2003a).*

Products:

- *The Watershed Management Decision Support System (WMDSS), a computer-based, interactive, multimedia decision support tool.*
- *A project map CD containing over 25 geospatial maps highlighting various land-cover/land-use properties in the Illinois River Basin.*
- *The Distributed Runoff nonpoint Pollution Model (DRIP).*
- *Virtual watershed fly-over maps that allow users to select various regions and investigate different environmental concerns and water quality parameters.*

User Community:

- *Policy and Decision-makers*
  - Results of this grant were distributed to the administrator of the Oklahoma Scenic Rivers Commission who has the responsibility for overseeing the management of the Illinois River basin in Oklahoma.
  - The project's findings were integrated into the background document of the 2003 Oklahoma Academy for State Goals leadership conference, which is charged with addressing energy and water policy in the state.
- *Stakeholders*
  - A major user-oriented document derived from this project, "Swimming Upstream: Collaborative Approaches to Watershed Management," will soon be published and covers the state-of-the-art in stakeholder based decision making for watershed management.

- *Legislators*
- *U.S. Environmental Protection Agency*
- *Academic Associations*

Themes:

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

This study aimed to identify and compare different environmental and social values held by stakeholders in the Illinois River watershed, and then test a management protocol that is technically effective, economically efficient, and socially and politically acceptable (Meo et al., 2000). The assessment of historical information, sampling data, and model simulations was also used to characterize the River and to determine ecological conditions and future ecological risk.

Investigators conducted many interviews with individuals living, recreating, conducting business, and regulating activities within the Illinois River Basin. The goal of the interviews was to develop a better understanding about the community's attitude toward the present state of their environment and the Illinois River. Interview discussions focused on stakeholder concerns regarding activities that were adversely impacting the river basin, as well as their preferences for managing these activities. The interview assessments revealed activities affecting water quality to be of greatest concern among stakeholders; however, this concern tended to be identified with preserving the aesthetic value of the River rather than with protecting public health and recreation (Meo et al., 2002). Pollution from poultry farming and the impacts of septic tanks on water quality were also of significant concern to stakeholders. Investigations into current management practices and management preferences revealed that stakeholders did not feel immediately responsible for factors impacting the watershed and disfavored controls on their own operations. In addition, stakeholders, such as farmers, strongly opposed any efforts by decision-makers to implement rules or management decisions that would restrict the use of private lands and/or impose economic burden.

Negotiation workshops were also conducted with policy-makers and stakeholders to develop policy proposals that could be used to address the issues and concerns raised during the interview assessments and surveys. Results of these workshops led to the development of three policy proposals and provisions for improving the condition of the Illinois River watershed. These proposals include a phosphorus management policy, a riparian area protection policy, and an alcohol and behavior control policy. The legitimacy of these three policy proposals was tested using a random sample telephone survey of approximately 460 stakeholders. The survey results confirmed that all provisions of the three policy proposals were highly satisfactory (Phosphorus management policy: 95% satisfaction; Riparian area protection policy: 91% satisfaction; Alcohol and behavioral control policy: 85% satisfaction) (Meo et al, 2003a).

Biological and ecological investigations were conducted to assess the health of fish, bottom dwelling macroinvertebrate, diatom, and phytoplankton communities within the watershed. Indicators of biological health showed that fish communities showed no significant trend towards improvement, and populations varied from poor to excellent over the period of record (Meo et al., 2000). Results of microinvertebrate and diatom studies showed that the biological quality of the small streams studied varied from very poor to good (Meo et al., 2000).

Nutrient loading and water quality investigations were also conducted. Results of the investigations revealed that animal waste is the primary source of nutrients in the watershed. Based upon nitrogen and phosphorus production, it was calculated that the animals in the basin are equivalent to approximately 5 and 15 million people, respectively (Meo et al., 2003b). In addition, it was calculated that 72 percent of human-generated waste is discharged to septic tanks (Meo et al., 2003b). Surprisingly, the amount of

human-generated nutrients is equivalent to at most 1 to 2 percent of the nutrients that are produced by animals (Meo et al., 2003b).

The information and results obtained from this research were used to develop simulations of the nutrient concentrations of the rivers within the Illinois River watershed as compared to the community-gathered data. These simulations have been integrated and formatted into a computer-based decision support tool called the Watershed Management Decision Support System (WMDSS). WMDSS is an interactive, multimedia tool that incorporates physical, biological, economic, and sociopolitical data along with photography and geographic information system (GIS) base-maps to produce visual images that simulate impacts within the Illinois River watershed. This computer program allows information pertaining to management alternatives to be more accessible to decision-makers. In addition, it provides a way for stakeholder groups to better understand the current state of the River and assists them with their discussions and negotiations regarding both current and future management strategies and activities.

2.9 STAR Grant R825792

Impact of Social Systems on Ecology and Hydrology in Urban-Rural Watersheds: Integration for Restoration.

Principal Investigator: Steward Pickett, Institute of Ecosystem Studies

Successes and Lessons Learned:

- *Collected data that improved the understanding of the heterogeneity in urban and suburban soils and the ecological structure of metropolitan areas.*
- *The new soil maps developed under this grant are of a resolution fine enough to parameterize hydrological models using components of both built and natural environments.*
- *The Regional Hydrological and Ecosystem Simulation System (RHESys) model developed under this grant has shown to perform better than industry standard hydrologic models.*
- *New measurements express heterogeneity in metropolitan areas more effectively than the standard structure, because of linking social patch structure with ecological patch data.*
- *Successfully built an effective network of interactions with Baltimore stakeholders and managers.*

Products:

- *An improved framework to link hydrology, ecology, and social sciences.*
- *A refined Regional Hydrological and Ecosystem Simulation System (RHESys) model linking urban hydrology, social, and ecological processes.*
- *Improved metropolitan patch mosaic for Baltimore incorporating social, ecological, and hydrological patch information.*
- *The School Partnership Program.*
- *Educational and outreach materials and activities.*
- *A framework for the analysis of land-use models and social field data collection methods.*
- *Soil maps with improved resolution scales.*
- *A model that networks interactions with stakeholders and managers in the Baltimore region.*
- *Multidisciplinary workshop to assess the state of knowledge and research needs concerning metropolitan Baltimore's water-related infrastructure.*

User Community:

- *Baltimore city, county, and state agencies concerned with water quality and water flow in metropolitan Baltimore.*
- *Educational institutions involving teachers and students from kindergarten through twelfth grade.*
- *Non-governmental organizations such as watershed associations and community groups.*

Themes:

Politics and Policies, Multi-criteria Studies

This project aimed to provide decision-makers with options to improve water quality using a newly developed watershed model that integrates social, ecological, and hydrological processes occurring within a watershed system. The goal was to provide a "user-friendly" decision-making tool that simulates natural surfaces, built surfaces, and source areas at multiple spatial scales characteristic of urban areas (Pickett et al., 2003a).

Research under this grant was conducted in the Gwynns Falls watershed in Baltimore, Maryland. Gwynns Falls is a 17,000 hectare watershed that drains into the Chesapeake Bay. This area encompasses land that has been undergoing a transition from agriculture to suburban development (Pickett et al., 2003c).

The model that has been created is based on two existing hydrologic models—the Hydrological Simulation Program – FORTRAN (HPSF) model and the Regional HydroEcological Simulation System (RHESSys). To calibrate the new model, researchers collected biological and ecological data in the sub-watersheds of Gwynns Falls that encompass both rural and urban areas of metropolitan Baltimore. Nitrogen cycling and microbial (cell) processes in soil were studied along with soil organisms including earthworms and arthropods (insects, spiders, and crustaceans). Water chemistry and benthic (bottom dwelling) invertebrate data were used to investigate how water quality responds to various types of urban land cover. Vegetation processes, environmental hazards, and toxic releases within the watershed were also investigated.

Researchers also studied the social processes that drive and are affected by bio-geophysical (both biological and geological) processes in the urban ecosystem (Pickett et al., 2003c). Social area analyses were used to assess potential impacts to watershed dynamics, as well as water quality and quantity. In addition, workshops and meetings were conducted with policy-makers and managers. Outcomes from these meetings were used to refine the model and explore user-friendly interfaces.

Once calibrated the new model was tested in a small area of the Gwynns Falls watershed. Results of the model simulations verified that the model was capable of generating realistic fluctuations in water, nitrogen, and carbon over time (Pickett et al., 2003b). Final results indicate that this new Regional Hydrological and Ecosystem Simulation System (RHESys) model performs better than the industry standard for the mixed, urban watersheds in the metropolitan area. (Picket et al., 2003d). While the data and the models produced under this grant are focused on the Baltimore metropolitan area in Maryland, this approach can serve as a model for other watersheds undergoing urban transitions.

2.10 STAR Grant R826282

An Integrated Watershed Approach to Evaluate and Model Ecosystem Effects of Erosion and Pollutant Transport in Urbanized Subalpine Landscapes

Principal Investigator: Charles R. Goldman, University of California

Successes and Lessons Learned:

- *Identified that the five major sources of nutrients impacting Lake Tahoe are: atmospheric deposition and precipitation, stream discharge, overland runoff, groundwater, and shoreline erosion.*
- *Inorganic fine particulate matter is a significant factor contributing to the degradation of Lake Tahoe.*

Products:

- *A generalized watershed hydrology model that can be applied in any watershed.*
- *Water Clarity Model for Lake Tahoe that allows agencies and decision-makers to assess the Lake's response to various levels and stages of watershed management.*
- *An Erosion and Sediment Transport model.*
- *A new meteorological station in Tahoe City.*
- *A detailed and reliable geochronology of Lake Tahoe.*

User Community:

- *Policy and Decision-makers*
  - The Nevada Division of Environmental Protection and the Lahotan Regional Water Quality Control Board. Together these two agencies produce and publish the Lake Tahoe Nutrient and Sediment Total Daily Maximum Load Newsletter.

Themes:

Politics and Policies, Urban, Restoration

The aim of this study is to develop a multi-disciplinary program designed to provide watershed managers and decision-makers with a science-based understanding of, and innovative tools for, the development of environmental policy (Goldman et al., 2003a). The focus of this study is Lake Tahoe in Sierra Nevada, California. The objectives of the research conducted in this area as highlighted by investigators were to:

- Implement a hydrologic model that has the ability to describe dynamics of non-point source pollutants over complex landscapes;
- Study the interactions between inorganic suspended particulate matter, chlorophyll, light and the natural mixing of the lake;
- Study the lake and watershed responses to historical disturbance;
- Develop a watershed scale erosion control management plan with existing agency and non-profit conservation groups.

Data indicate that environmental conditions of Lake Tahoe have been deteriorating since the 1960s. Water clarity is of particular concern. It is estimated that under current conditions the clarity of the Lake will be lost within 30 years (Goldman et al., 2003b). Researchers feel that reductions in phosphorus and fine-sediment loading are critical to reducing this decline in water clarity (Goldman et al., 2003b). A critical component for long-term planning at Lake Tahoe will be a tool that can be used to assess the Lake's capacity to receive and process sediment and nutrients. By knowing the level of loading that would attain the desired lake conditions, responsible agencies will be better able to plan in a more quantitative and progressive manner (Goldman et al., 2003b). As a result of this need, researchers under this grant have developed a water clarity model consisting of three major components:

- Hydrodynamics (physical processes) including water motions, mixing, waves, particle settling, etc.;
- Water quality (algal growth related) which includes nutrient uptake and cycling, and dissolved oxygen;
- Optical properties (secchi depth) that includes the absorption and scattering of light by organic and inorganic particles (Goldman et al., 2003c).

Based on these parameters, this model has the ability to identify, by year, the total allowable amount of nutrient loading to achieve the desired water clarity effect in Lake Tahoe and will therefore provide regulators with a tool to establish targets for loading reduction. In addition, this model is general enough to be applied to variety of aquatic settings and can be used as a tool for assessing eutrophication in other waterbodies (Goldman et al., 2003b).

A physically-based hydrologic watershed model was also developed under this grant to aid in the prediction of erosion and sediment transport from Lake Tahoe's multiple watersheds. The purpose of this model was to provide a tool that could be used to:

- Measure the effect of changes (e.g., roads, urbanization) to land surface/vegetation on the water, sediment and nutrient balances;
- Forecast flooding;
- Assess long-term water balances (i.e., the long-term discharges to surface waters that take into consideration natural and man-made episodes impacting a waterbody such as precipitation, water withdrawals, wastewater recycling etc.) at Lake Tahoe under various scenarios of future climate change (Goldman et al., 2003b).

The model was tested extensively in the Ward Creek watershed of Lake Tahoe. Results of the tests revealed that the model was successful in simulating environmental conditions within the watershed and had the ability to identify areas in the watershed that should be set for priority restoration. The development of this hydrologic model has built a base for modeling erosion and sediment transport and can be applied to the assessment of erosion processes in upland and in-stream areas.

The results of the research and modeling at Lake Tahoe have direct transferability to other regions in the mountainous U.S. where agencies and communities are striving to incorporate a sound science-based foundation into their efforts to protect their watersheds (Goldman et al., 2003a).

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APPENDICES

APPENDIX A. 1997 WATER AND WATERSHED GRANTS SUMMARY TABLE

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825751	A Study of the Effects of Natural and Anthropogenic Processes on Tillmook Bay and its Watershed: An Integrated Process Study and Land-Use Perspective	McManus, J. – Oregon State University, College of Ocean and Atmospheric Science	• Politics and Policies • Multi-criteria Studies	• Examined the relative influences of natural and human induced processes within the watershed system and how it impacts the health of an estuary. Understanding the relationship between the watershed and estuarine system plays a critical role in developing sound management practices to protect these environments.	• A salmon cycle learning game for school children. • Outreach materials including media presentation and video programming. • Tillamook County Performance Partnership Outreach Task Force to improve the exchange of information between scientists and local citizens.	• Research helped evaluate the role of ocean processes in estuarine systems. • Research findings brought about a better understanding of the role of man-made and natural influences on water quality in Tillamook Bay. • Transport paths and accumulation patterns of sediments were successfully established within Tillamook Bay. • Investigators developed a better understanding of the impacts of timber harvesting (the removal of trees for lumber), agriculture, and salvage logging (the selected removal of trees susceptible to fire, insect attach or disease) on in-stream conditions in the Tillamook and Kilchis sub-basins.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825757	Development and Social and Ecological Transferability of Integrated Ecological Assessment Models	Deegan, L. – Marine Biological Laboratory, Ecosystems Center	• Politics and Policies • Restoration • Scientific Technique	• Investigated the problems associated with excess nitrogen loading and how it relates to various land-use practices in estuarine areas.	• A tutorial website designed to teach users the impacts of land use on water quality and living resources in the coastal estuaries of southern New England (*http://ecosystems.mbl.edu/Research/Clue/*) • CLUE (Changing Land Use and Estuaries) ecosystem response model. • An Index of Estuarine Biotic Integrity (EBI) • Two new survey instruments to investigate perceptions regarding the utility and applicability of nitrogen-loading models as decision-making aids.	• Ecosystem modeling is an accurate method of predicting ecosystem responses to land use and land-use change. • Models are a cost effective way to gain competent data about existing and likely future land uses. • The utility of policy models is often hindered by their complexity. • To improvement watershed management through the use of models in local decision-making, partnerships must be made between modelers and users so they may reflect the more immediate interests and needs of local citizens and managers. • Models have the potential to be misused as users may misinterpret results or use the models strategically to support preconceived agendas. Models can also be distorted by the personal values and policy judgments of the developer.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825758	Community Values and the Long-term Ecological Integrity of Rapidly Urbanizing Watersheds	Beck, B.M. – University of Georgia	• Urban • Politics and Policies • Multi-criteria Studies	• Explored different approaches to maintaining the integrity of an environmental system based on short- and long-term community values.	• A framework for adaptive community learning to identify stakeholder concerns and develop the target futures of Lake Lanier. • A model of Lake Lanier that incorporates new data on the microbial food web and sediment biochemistry of the Lake.	• Using the concept of adapted community learning, researchers discovered that stakeholders are more concerned about the longer-term than shorter-term well being of Lake Lanier. • Developed a concept of environmental decision-making that would enable science-based models to be responsive to both the short- and long-term community values. • Improved the understanding of ecosystem behavior within Lake Lanier and identified key elements of the current state of the lake and its future inputs. • Conducted a "Foresight Workshop" to help stakeholders and decision-makers plan for the future of Lake Lanier. • Stakeholders' greatest concern for Lake Lanier was public health, not ecological integrity. • Based on research and model results, the optimistic views on the future of Lake Lanier are close to three times more likely to occur than the pessimistic outlooks on the future. • Successfully remedied two prior limitations of Regionalized Sensitivity Analysis (RSA) by adjoining a Tree-Structured Destiny Estimation (TSDE) procedure to assess multivariate features by circumventing small-sample size problems, using a Uniform Covering with Probabilistic Rejection (UCPR) algorithm.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825759	Risk Based Urban Watershed Management – Integration of Water Quality and Flood Control Objectives	Novotny, V. – Marquette University	• Urban • Economics • Multi-criteria Studies • Politics and Policies	• Identified and quantified the potential risks to human, biological and environmental health due to contamination from urban and suburban watershed development. The mathematical formulas developed could assess the risk involved with different management methods in urbanized watersheds.	• Foundation of the Institute of Urban Environmental Risk Management at Marquette University. • Methodology for evaluating risk due to flooding supported by a GIS-based application. • An improved methodology for assessing ecological risk due to water column contamination. • A GIS-based urban watershed pollutant-loading model.	• Urbanization has negative impacts on fish community structure and macroinvertebrate health. • Analyses indicate that lead presents the highest ecological risk to waterbodies. • Variables, such as income and education, as well as location within the flood plan, have little effect on local citizens' willingness to pay for management projects. • Research helped in the advancement of the risk-based approach to water quality management. • The pollution-loading model developed, can assist TMDL programs and studies by providing a tool to assess the effect of pollution on the integrity of the receiving waterbodies. • As a result of this grant work, the Institute of Urban Environmental Risk Management has become the center of environmental research at Marquette University.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825**760**	Landscapes and Waterscapes: An integrating Framework for Urbanizing Watersheds	Diplas, P. – Virginia Polytechnic Institute and State University	• Urban • Politics and Policies • Economics • Multi-criteria Studies • Restoration	• Produced results that can help decision- makers find the best land usage scenarios for a variety of development situations in different communities experiencing different rates of urban growth.	• A hydrologic modeling framework for assessing the impacts of alternative landscapes on surface and subsurface water flows • A new strategy for modeling flow patterns via channel topography and complexity. • Three spatial hydraulic metrics to aid in locating and distinguishing biologically important features. • Procedures for predicting the response of fish and macroinvertebrate communities to urbanization-induced changes to biological and hydrologic conditions. • A conceptual model for predicting land prices based on characteristics of urban development and land use. • A simulation model to predict water and sewer costs as a function of the spatial distribution of services. • A computer simulation model to estimate the annualized cost of delivering water and sewer service to residential areas. • A web-based model integrating the hydrological and economic aspects of this study. • Proceedings of the “Integrated Decision-Making for Watershed Management” conference.	• Impact to watershed hydrology increased as land conversion became more drastic. • The presence and amount of pollutants in sampled fish species indicate that fish may be an excellent biomarker of environmental and water contamination, and may have the ability to serve as a warning system for human health hazards. • Economic analyses reveal that both residents and local governments derive economic benefits from sprawling developments. • Increased area of impervious surfaces due to urban development is the most significant indicator of hydrologic change. • Hydrologic impacts associated with the expansion of existing communities have less impact on water flow and discharge than those associated with new community developments.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825**761**	An Integrated Ecological and Socio-Economic Approach to Evaluating and Reducing Agricultural Impacts on Upper Mississippi River Watersheds	Gowda, P. – University of Minnisota	• Agriculture • Politics and Policies	• Assessed agricultural impacts to water quality and ecosystem health within a watershed system. • Evaluated the potential water quality benefits associated with adopting various agricultural best-management practices at the farm level.	• Model of the Lower Minnesota River watershed. • A calibrated ADAPT model to predict flow, sediment, and nitrate loadings. • A set of alternative agricultural management practices for the Lower Minnesota River watershed. • A comprehensive GIS Database for the Lower Minnesota River and Maquoketa River watersheds.	• Identified key factors that affect the adoption of conservation farming practices through the use of a socioeconomic study. • The Agricultural Drainage and Pesticide Transport (ADAPT) model is not suitable for simulating condition in areas dominated by urban land use. • Regional variations in landscape characteristics can have a strong effect on stream communities and, therefore, management plans may be more effectively approached from the watershed scale • Large-scale changes in agricultural land-use practices can affect the local biological integrity of streams even in highly disturbed basins. • Farmers in the study watershed were actively seeking information about soil and water conservation practices. However, the production practices used by these farmers tended to offset the positive environmental effects of the conservation practices they were adopting. • In the Lower Minnesota River watershed conservation tillage practices are adopted for reasons other than soil conservation. • In both the Maquoketa River and Minnesota River watersheds, the existing rate of adoption of soil conservation tillage was strongly related to Benthic Macroinvertebrate Index of Biological Integrity (BM-IBI) scores. • Universal Soil Loss Equation (USLE) may serve as an important tool for designing watershed biomonitoring programs.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825762	Linking Watershed-Scale Indicators of Changes in Atmospheric Deposition to Regional Response Patterns	Kahl, J.S. – University of Maine	• Politics and Policies	• Evaluated the response of surface waters to various levels of acidification and assessed there ability to recover. • Linked scientific knowledge to the practical needs of decision-makers.	• Adapted the Tracking and Analysis Framework (TAF) to Maine watersheds.	• Declines in atmospheric deposition of sulfates have led to a decrease in sulfate concentrations in surface waters in Maine; however, the expected recovery of these watersheds from acidification has been minimal, and in some instances acidification has increased. • The inability of Maine watersheds to recover from acidic conditions may be the result of decreases in concentrations of base cations (i.e., calcium and magnesium) in these waterbodies. • The effects of climate change and climate variability may be influencing the acid-base chemistry of Maine watersheds in undetermined ways. These effects might even be counteracting the positive effects of decreased acid deposition. • Atmospheric loading of nitrogen may be influencing the acid-base status of Maine watersheds in undetermined ways.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825**791**	Ecological Risks, Stakeholder Values and River Basins: Testing Management Alternatives for the Illinois River	Meo, M. – University of Oklahoma	• Agriculture • Politics and Policies • Economics • Multi-criteria Studies	• Identified and compared different environmental and social values held by stakeholders. • Developed and tested a management protocol that is technically effective, economically efficient, and politically acceptable.	• The Watershed Management Decision Support System (WMDSS), a computer-based, interactive, multimedia decision support tool. • A project map CD containing over 25 geospatial maps highlighting various land-cover/land-use properties in the Illinois River Basin. • The Distributed Runoff nonpoint Pollution Model (DRIP). • Virtual watershed fly-over maps that allow users to select various regions and investigate different environmental concerns and water quality parameters.	• Disagreements exist over the magnitudes and causes of problems in the Illinois River, as well as over who is to blame and what should be done to solve these problems. • Stakeholders are most concerned and knowledgeable about problems and associated impacts that are visible, local, and have media attention—including alcohol consumption, inappropriate behavior by tourists, and littering. Stakeholders, therefore, tend to consider management policies focused on preserving the aesthetic value of the River system to be of greater importance than policies for protecting public health and recreation. • Policy-makers are most concerned with less visible, widespread, water quality-based problems and issues such as nutrient loading from over application of fertilizer, municipal waste, and riparian area protection. • Poultry farming and the impacts of septic systems were viewed to be the greatest threat to water quality in the Illinois River watershed. • Agricultural areas were discovered to be the most significant contributors to phosphorus loading during runoff. • Distrust between stakeholders and government officials—particularly the federal government—are high. Stakeholders have an overwhelming preference to participate directly in the policy making process as opposed to deferring to government discretion. • Stakeholders prefer coercive policies regarding enforcement of existing laws and regulations, such as apply to point source discharge and civil law regarding behavior. Stakeholders also prefer educational and voluntary strategies with compensation for economic losses from management of less regulated activities (e.g., farming and rural/suburban land use).

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R825792	Impact of Social Systems on Ecology and Hydrology in Urban-Rural Watersheds: Integration for Restoration	Pickett, S. – Institute of Ecosystem Studies.	• Politics and Policies • Urban • Multi-criteria Studies	• Utilized social, ecological, and hydrologic processes occurring in a watershed system to create a model for developing water-quality management strategies in watersheds undergoing urban transitions.	• An improved framework to link hydrology, ecology, and social sciences. • A refined Regional Hydrological and Ecosystem Simulation System (RHESys) model linking urban hydrology, social, and ecological processes. • Improved metropolitan patch mosaic for Baltimore incorporating social, ecological, and hydrological patch information. • The School Partnership Program. • Educational and outreach materials and activities. • A framework for the analysis of land-use models and social field data collection methods. • Soil maps with improved resolution scales. • A model that networks interactions with stakeholders and managers in the Baltimore region. • Multidisciplinary workshop to assess the state of knowledge and research needs concerning metropolitan Baltimore's water-related infrastructure.	• Collected data that improved the understanding of the heterogeneity in urban and suburban soils and the ecological structure of metropolitan areas. • The new soil maps developed under this grant are of a resolution fine enough to parameterize hydrological models using components of both built and natural environments. • The Regional Hydrological and Ecosystem Simulation System (RHESys) model developed under this grant has shown to perform better than industry standard hydrologic models. • New measurements express heterogeneity in metropolitan areas more effectively than the standard structure, because of linking social patch structure with ecological patch data. • Successfully built an effective network of interactions with Baltimore stakeholders and managers.

Grant Numbers	Grant Title	Principal Investigator	Common Themes	Relevance	Products	Successes/ Lessons Learned
-R82**6282**	An Integrated Watershed Approach to Evaluate and Model Ecosystem Effects of Erosion and Pollutant Transport in Urbanized and Subalpine Landscapes	Goldman, C.R. – University of California	• Policy and Politics • Restoration	• Developed a water clarity and hydrologic watershed model that have direct transferability to other regions in the mountainous U.S. to assist in the protection of watersheds. The water clarity model is general enough to be applied to a variety of aquatic settings and can be used as a tool for assessing eutrophication in numerous waterbodies.	• A generalized watershed hydrology model that can be applied in any watershed. • Water Clarity Model for Lake Tahoe that allows agencies and decision-makers to assess the Lake's response to various levels and stages of watershed management. • An Erosion and Sediment Transport model. • A new meteorological station in Tahoe City. • A detailed and reliable geochronology of Lake Tahoe.	• Identified that the five major sources of nutrients impacting Lake Tahoe are: atmospheric deposition and precipitation, stream discharge, overland runoff, groundwater, and shoreline erosion. • Inorganic fine particulate matter is a significant factor contributing to the degradation of Lake Tahoe.

APPENDIX B. 1997 WATER AND WATERSHED GRANTS COMMON THEMES CHART

	Restoration	Multi-criteria Studies	Urban	Agriculture	Economics	Politics and Policies	Scientific Techniques
R825**751**		X				X	
R825**757**	X					X	X
R825**758**		X	X			X	
R825**759**		X	X		X	X	
R825**760**	X	X	X		X	X	
R825**761**				X		X	
R825**762**						X	
R825**791**		X		X	X	X	
R825**792**		X	X			X	
R826**282**	X					X	

APPENDIX C. 1997 WATER AND WATERSHED GRANTS COMMON THEMES

Restoration:

R825760 - **From Landscapes to Waterscapes: An Integrating Framework for Urbanizing Watersheds** - Diplas, P.
Many communities cannot afford the costs associated with management and restoration programs to repair degraded streams and biotic integrity of other aquatic wildlife. Research conducted under this grant sought to assess these issues and provided managers and decision-makers with the tools to develop plans to ensure environmental quality at an affordable price to residents.

R825757 - **Social and Ecological Transferability of Integrated Ecological Assessment Models** - Deegan, L.
The development of an index of estuarine biotic integrity (EBI) has proven to be a useful tool for assessing efforts to restore submerged aquatic vegetation.

R826282 - **An Integrated Watershed Approach to Evaluate and Model Ecosystem Effects of Erosion and Pollutant Transport in Urbanized Subalpine Landscapes** - Goldman, C.R.
The hydrologic watershed model developed is successful in simulating environmental conditions within a watershed and has the ability to identify areas in a watershed that should be set for priority restoration.

Multi-criteria Studies:

R825751 - **Effects of Natural and Anthropogenic Processes on Tillamook Bay and Its Watershed: An Integrated Process Study and Land-Use Perspective** - McManus. J.
Research assessed sedimentary budgets; carbon, nutrient, and trace metal cycles; aquatic ecosystem health and biotic integrity; and differences between local knowledge and scientific observations to uncover the effects of various land-use practices on the physical, chemical, and biological conditions in a watershed system.

R825758 - **Community Values and the Long-term Ecological Integrity of Rapidly Urbanizing Watersheds** – Beck, M.B.
Research integrated ecological, hydrological, and social/policy sciences to understand community values and ecosystem behavior.

R825759 - **Risk Based Urban Watershed Management-Integration of Water Quality and Flood Control Objectives** - Novotny, V.
Assessed economic, biological, and habitat conditions in urbanized watersheds.

R825760 - **From Landscapes to Waterscapes: An Integrating Framework for Urbanizing Watersheds** - Diplas, P.
Research focused on addressing hydrology and hydraulics, biology, economics and policy, and the problem solving environment to uncover and assess the impact of land-use on a watershed system.

R825792 - **Impact of Social Systems on Ecology and Hydrology in Urban-Rural Watersheds: Integration for Restoration** - Pickett, S.
Utilized social, ecological, and hydrologic data to develop a Regional Hydrological and Ecological Simulation System (RHESys) model.

Urban:

R825758 - **Community Values and the Long-term Ecological Integrity of Rapidly Urbanizing Watersheds** – Beck, M.B.
Integrated ecological, hydrological, and social/policy science to develop a concept of environmental decision-making that would help to preserve the long-term ecological integrity in a watershed undergoing rapid urbanization.

R825759 - **Risk Based Urban Watershed Management-Integration of Water Quality and Flood Control Objectives** - Novotny, V.
Examined urban waterbodies and assessed the degree to which urban development influences flood risks and the waterbody ecology.

R825760 - **From Landscapes to Waterscapes: An Integrating Framework for Urbanizing Watersheds** - Diplas, P.
Assessed the hydrological consequences associated with urban development in a watershed system.

R825791 - **Ecological Risks, Stakeholder Values, and River Basins: Testing Management Alternatives for the Illinois River** - Meo, M.
Conducted studies and incorporated physical, biological, economic, and sociopolitical data to develop watershed management decision-making aids such as models, maps, and interactive web applications.

R825792 - **Impact of Social Systems on Ecology and Hydrology in Urban-Rural Watersheds: Integration for Restoration** - Pickett, S.
Developed a tool for assessing water quality, focusing on a watershed system undergoing a transition from agricultural land to suburban land.

Agriculture:

R825761 - **An Integrated Ecological and Socio-Economic Approach to Evaluating and Reducing Agricultural Impacts on Upper Mississippi Watersheds** - Gowda, P.
Predicted flow, sediment loadings, and nitrogen loadings from agriculturally dominated areas, as well as the success of different alternative conservation farming techniques on preserving/improving water quality using a calibrated version of the Agricultural Drainage and Pesticide Transport (ADAPT) model.

R825791 - **Ecological Risks, Stakeholder Values, and River Basins: Testing Management Alternatives for the Illinois River** - Meo, M.
Stakeholders in the study area of the Illinois River Basin viewed pollution from agriculture, namely poultry farming, and its impacts on water quality as one of the biggest concerns. It was discovered that animal waste from these areas was the primary source of nutrients to the Illinois River, and generated approximately 98-99 percent more nutrients than humans.

Economics:

R825759 - **Risk Based Urban Watershed Management-Integration of Water Quality and Flood Control Objectives** - Novotny, V.
Assessed the financial feasibility of different types of management plans based on residents' willingness to pay for watershed management projects. Cost models were developed to for urban watershed management to help create a better picture of the financial and environmental risks associated with different watershed management styles.

R825760 - **From Landscapes to Waterscapes: An Integrating Framework for Urbanizing Watersheds** - Diplas, P.
Developed a series of economic models to predict land prices, as well as water and sewer costs based on varying degrees and characteristics of urban development and land use.

R825791 - **Ecological Risks, Stakeholder Values, and River Basins: Testing Management Alternatives for the Illinois River** - Meo, M.
Socioeconomic research found that stakeholders tended to oppose any efforts by decision-makers to implement watershed management rules or plans that would impose economic burden.

Politics and Policies:

R825751 - **Effects of Natural and Anthropogenic Processes on Tillamook Bay and Its Watershed: An Integrated Process Study and Land-Use Perspective** - McManus. J.
Provided information to help clarify scientific findings related to the issues discussed within the community and to assist local managers and decision-makers in developing sound management practices.

R825757 - **Social and Ecological Transferability of Integrated Ecological Assessment Models** - Deegan, L.
The creation of the estuarine response model provides a useful tool that can assist decision-makers and planners with the development of scientifically sound land-use management strategies at the local level. Decreasing model complexity and increasing communications between modelers and potential users also ensures the models better serve community and watershed management goals.

R825758 - **Community Values and the Long-term Ecological Integrity of Rapidly Urbanizing Watersheds** – Beck, M.B.
Developed a concept of decision-making using science-based models that were responsive to identified community values.

R825759 - **Risk Based Urban Watershed Management-Integration of Water Quality and Flood Control Objectives** - Novotny, V.
Findings regarding the effects of urbanization can assist in the development of watershed management plans for different watershed systems and aid decision-makers and planners in choosing the best plans to reduce the impacts associated with urbanization.

R825760 - **From Landscapes to Waterscapes: An Integrating Framework for Urbanizing Watersheds** - Diplas, P.
The methodology for watershed assessment and the hydrologic, ecosystem, and economic models that were created help facilitate the development of watershed management policies by allowing managers and decision-makers to evaluate the consequences associated with varying watershed management strategies prior to implementation.

R825761 - **An Integrated Ecological and Socio-Economic Approach to Evaluating and Reducing Agricultural Impacts on Upper Mississippi Watersheds** - Gowda, P.
The findings of this study are useful in the development of intervention programs that could help facilitate the adoption of soil and water protection practices at the farm level.

R825762 - **Linking Watershed-Scale Indicators of Change in Atmospheric Deposition to Regional Response Patterns** - Kahl, J.S.
Linked scientific knowledge to the practical needs of decision-makers to produce results that could be applied to management and policy decisions made by industries and governments at the local, state, and federal level. Results had a direct influence on the policy and legislation mandated under the Clean Air Act.

R825791 - **Ecological Risks, Stakeholder Values, and River Basins: Testing Management Alternatives for the Illinois River** - Meo, M.
The information and tools developed in this study provide stakeholders with a better understanding about the current state of the Illinois River and assists them in their discussion and negotiations regarding both current and future management strategies and activities.

R825792 - **Impact of Social Systems on Ecology and Hydrology in Urban-Rural Watersheds: Integration for Restoration** - Pickett, S.
Provides decision-makers with options to improve water quality within a watershed system undergoing urbanization, using a newly developed Regional Hydrological and Ecological Simulation System (RHESys) model.

R826282 - **An Integrated Watershed Approach to Evaluate and Model Ecosystem Effects of Erosion and Pollutant Transport in Urbanized Subalpine Landscapes** - Goldman, C.R.
Developed a multi-disciplinary program designed to provide watershed managers and decision-makers with a science-based understanding of environmental policy, and developed innovative tools for developing sound policy actions.

Scientific Techniques:

R825757 - **Social and Ecological Transferability of Integrated Ecological Assessment Models** - Deegan, L.
Developed a new index of estuarine biotic integrity (EBI) as a tool to measure ecosystem function in a wide variety of estuarine habitats. The EBI has proven to be successful in measuring the effects of habitat change and efforts to restore submerged aquatic vegetation.