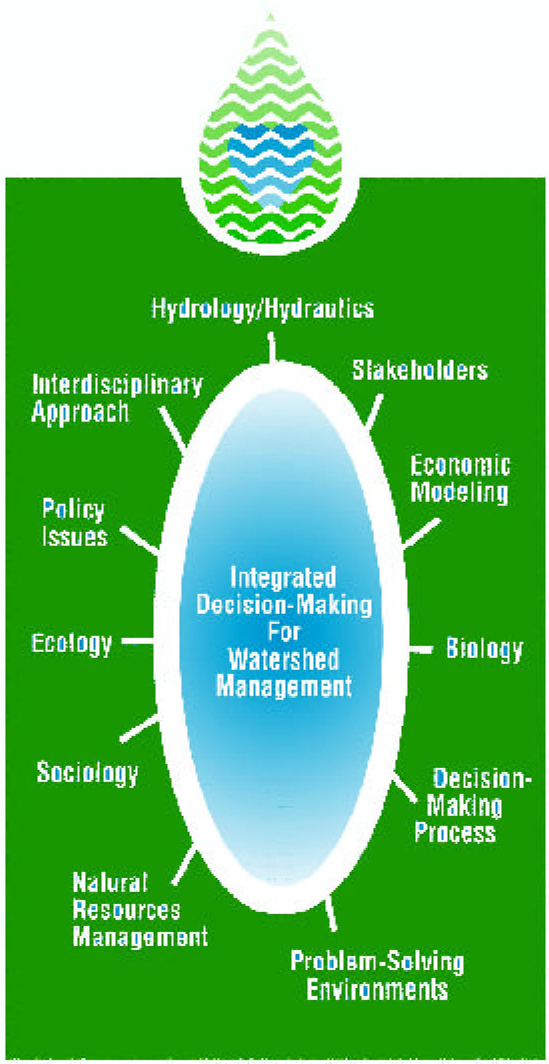
Abstracts

Integrated Decision-Making for Watershed Management Symposium: Processes and Tools



January 7-9, 2001
National 4-H Conference Center
Chevy Chase, Maryland

Hosted by

Virginia Tech

Blacksburg, Virginia

ABSTRACTS

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Editor

Darrell Bosch

Hosted by Virginia Tech

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Leonard A. Shabman, Director

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Session 1-A. Integrating Physical and Socioeconomic Models--1

Weighing the Costs and Benefits of Protecting Water Quality in the Catawba River Basin

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The primary objective of this study was to estimate the economic value of protecting the current level of water quality in the Catawba River basin over time. Economic benefits were estimated using a stated preference survey methodology to value survey respondents' willingness to pay for a management plan to protect water quality in the Catawba basin over time. A cost/benefit analysis was then performed to determine if this proposed management plan would result in benefits in excess of its potential costs. Telephone interviews were completed with 1085 randomly selected households, who were also mailed a short information booklet about these issues. Respondents expressed a mean willingness to pay of $139 for a management plan designed to protect water quality at its current level over time. This translates to an annual economic benefit of over $75 million for all taxpayers in the 16 Catawba basin counties. The costs of this management plan were estimated and then compared with the benefit measures over a ten-year period. The resulting cost/benefit analysis indicated that the potential benefits of this management plan would outweigh the costs by $100.9 million.

Application of An Environmental and Economic Modeling System for Watershed Assessments

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A National Pilot Project (NPP) on Livestock and the Environment was initiated in 1992 to help provide solutions to environmental problems associated with livestock production. A major development of the NPP was the Comprehensive Economic and Environmental Optimization Tool - Livestock and Poultry (CEEOT-LP), an integrated modeling system designed to produce economic and environmental indicators for alternative policy scenarios applied to intensive livestock production watersheds. The system consists of a farm-level economic model (FEM) and two environmental models: the field-scale APEX model and the watershed-level SWAT model. To date, CEEOT-LP has been applied to two watersheds in Texas and one in Iowa. Predicted reductions in P losses for two P-based manure application rate scenarios, relative to baseline conditions, ranged from –4 to –54% across the three watersheds; however, N loss impacts ranged from a decrease of –34% to an increase of 79%. For five other alternative scenarios that were simulated for only one watershed, N and P loss impacts ranged between a reduction of –78% to an increase of 20%. Aggregate watershed-level economic impacts of the seven scenarios spanned a spectrum of a –27% decrease to a 25% increase in income, relative to the baseline.

A Bioeconomic Model of the Western Brazilian Amazon: Forest and Farm Production

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Annual land-use decisions of settlement farmers, estimated to approach half a million in the Amazon Basin, can have significant impacts on forest conversion and the watershed's climate. This study predicts whether settlement farmers in the western Brazilian Amazon will adopt more intensive production systems and, if they do, the impact of this adoption on deforestation and farm incomes. Adoption of four types of intensification-- no intensification, intensification of non-livestock activities on cleared land, intensification on all cleared land, and intensification on both cleared and forested land--and their economic and environmental impacts were predicted using a farm-level bioeconomic model. Bioeconomic models are models that simulate biophysical processes and economic activities based on optimization algorithms at the farm, watershed, regional, or national level. Intensified land uses on either the cleared or forested lands generate higher returns to labor and land, and thus will likely be adopted by small settlers. Intensification on cleared land increased deforestation. Intensification on forested land—low-impact forest management—slowed the deforestation rate, but did not stop it. Even with intensified activities on forested land, pasture still dominates the landscape. Given the current socioeconomic and political setting, existing intensification systems on the cleared land will not save the forest. Intensification systems on forested lands provide better hope because they increase the value of the standing forest counteracting the pressure to deforest but will require policy and institutional changes.

Probabilistic, Cost-Effective Point/Nonpoint Management in the Susquehanna River Basin

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Point/nonpoint trading has been suggested as a relatively efficient approach for reducing nutrient pollution in the Chesapeake Bay and elsewhere. However, relatively little economic research has examined the design of trading programs involving nonpoint sources. This paper considers several point/nonpoint trading programs for the Susquehanna River Basin in the Chesapeake Bay watershed. Each program is differentiated by the permit bases used for nonpoint sources, specifically, we analyze programs in which nonpoint permits are denominated in terms of expected loadings or the production inputs, land and nitrogen. Our results indicate that programs based on expected loadings are less costly than those based on inputs, transactions costs aside, when trading ratios are not spatially differentiated. A second result is that land use-based programs do little to reduce the expected social costs of pollution. Third, we find that the majority of control costs optimally fall on nonpoint sources, indicating a need for coordinated management. Finally, the trading ratios for emissions-for-expected loadings programs are much smaller than those found in existing markets, trading ratios for emissions-for-nitrogen programs are

much larger than ratios currently applied in existing markets, and the cost-effective ratios for each program can vary considerably depending on watershed characteristics.

Session 1-B. Stakeholder-Based Watershed Management

Involving Citizens in Watershed Planning: Lessons from Great Lakes Remedial Action Planning

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In 1972 Canada and the United States signed the Great Lakes Water Quality Agreement, an agreement to work mutually towards the remediation of the Great Lakes, which had become severely degraded. In the 1987 amendment of that agreement, the two nations determined to adopt a watershed approach to achieving the goals thereof. In the ensuing years, many lessons have been learned from this process about including citizens in watershed planning. This study presents an integrative review of three dissertations written about stakeholder involvement in the Remedial Action Plans, specifically addressing the lessons that can be derived from errors made. First, it is shown that clearly delimiting the role that citizens will play in the planning process is essential to their effective functioning. Second, considering existing institutions, in particular non-governmental organizations, can ensure the inclusion of those important stakeholders, whereas failure to consider these can ostracize important experts and undermine the goals of watershed planning. Third, in comparison, regulatory agencies are less effective facilitation organizations than planning organizations due in part to the history of interaction between citizen participants and the agency. Finally, establishing committees charged specifically with ensuring continuing participation can enhance the retention of participants through the planning and implementation stages.

Federal Environmental Law and the Occurrence of Collaborative Watershed Partnerships

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This paper tests two competing hypotheses regarding federal environmental laws and their affects on collaborative watershed management. Critics of the Endangered Species Act and Clean Water Act assert that the high-stakes, command-and-control nature of these laws breeds mistrust among stakeholders, leading to entrenched policy stances and a reluctance or inability to achieve creative, cooperative solutions. Proponents of these laws claim that, without their strong provisions for curtailing economic activity, resource users would have little incentive to engage environmental advocates at the negotiating table. These opposing arguments are assessed by analyzing the geographic distribution of all 150 watershed-based stakeholder partnerships in California. According to a logistic regression model, partnerships are more likely to occur in watersheds with (1) multiple competing claims on the resource,

(2) relatively high water quality, (3) high property values, and (4) high levels of Clean Water Act TMDL implementation. The latter result supports the hypotheses that federal environmental law can catalyze the early stages of collaborative resource management.

Involving Watershed Stakeholders in the Management of Nonpoint Source Pollution

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The development of effective solutions for addressing nonpoint source pollution on a watershed basis often involves watershed stakeholders. However, success in engaging stakeholders in collaborative decision-making processes varies, as watershed managers are faced with the challenges inherent to finding the right process for the decisions needed and in successfully engaging stakeholders in that process. Two characteristics that may provide guidance for determining the appropriateness of applying a collaborative process to a watershed problem are the need to collaborate and the willingness of stakeholders to engage in a collaborative decision-making process. By examining seven attributes of the decisions confronted by stakeholders in a collaborative process, the consequences of these attributes on the need for collaboration and stakeholders' willingness to engage can be estimated. The decision attributes include: level of uncertainty, balance of information, risk, time horizon of effects, urgency of decision, distribution of effects, and clarity of problem. The decision attribute model was applied to two different collaborative decision-making processes conducted by the same watershed stakeholder group.

Public Participation in an Integrated Resource Planning Process for Regional Water Supplies

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The state of Texas passed legislation in 1997 that established a process for developing a fifty-year state water plan through a bottoms-up approach involving representation from at least eleven recommended special interest groups.

Moorhouse Associates Inc. was contracted to develop and implement a Public Participation Plan for the South Central Texas Region. The two goals of the public process were to take planning information out to the public and to provide a format for bringing the public opinion back to the planning group. The overall goal of the project was to provide public input throughout the planning process that will facilitate the development of a water plan that is widely accepted by the public.

By using county government to establish focus groups, participation was encouraged from all of the twenty-one counties in the region. The tools used in the process included an Internet site, surveys, focus groups, public meetings, community group presentations, media communications and newspaper clippings.

The public participation process as implemented, maintained communication throughout the planning process and at key decision points. This ongoing communication helped alleviate an initial uneasiness with the integrated resource planning approach.

Session 2-A. Approaches for Risk Assessment

Watershed Ecological Risk Assessment: The Clinch and Powell Valley Experience

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A watershed approach based on partnerships, geographic focus and sound science is being used more frequently to address environmental problems. Ecological risk assessment is a process to collect, organize, analyze and present scientific information to improve decision-making. The process and benefits of combining the two approaches into watershed ecological risk assessment is described. This assessment approach is used in the Clinch and Powell Rivers basin to analyze land use, in-stream habitat quality and their effects on fish and mussels were analyzed. The assemblage of fish and freshwater mussel species in the Clinch and Powell Rivers of southwestern Virginia is among the most diverse and threatened in North America. A pilot study determined the optimal riparian buffer area to describe associations between land use, stressors and biota and that fish IBI was a useful surrogate for mussel species richness. Percent pasture area, percent cropland, and proximity to active mining, urban areas, or major transportation routes accounted for over half of the variance in fish IBI scores. Native fish and mussel populations appeared to be at greatest risk as more stressors co-occur. Such assessment findings will be used to help define management strategies.

A Trade-Off Weighted Index Approach: Integrating Economic and Ecological Analysis

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This study integrates economics analysis and ecological risk assessment to evaluate alternative environmental management scenarios. The methodology uses the outputs of the Clinch Valley Ecological Risk Assessment to define choice sets that are used in a conjoint analysis-based survey methodology to assess citizen's preferences for alternative states of the environment of the Clinch River Valley. The aquatic biodiversity of the Clinch River is threatened by agriculture, coal mining, urban development and other activities. The biodiversity resources provide an interesting challenge for assessing social benefits. Three different assessment methods are used. The first looks at trade-offs solely among environmental characteristics and develops an environmental preference index to evaluate management alternatives. The second method adds regional economic variables into the choice set, and the third uses a tax as a characteristic to allow the opportunity to measure willingness to pay.

Game Theory as a Watershed Management Tool: A Case Study of the Middle Platte Ecosystem

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The resource management problem for the Middle Platte ecosystem is that there is insufficient water available to meet both in-stream ecological demands and out-of-stream economic needs. This problem of multiple interest groups competing for a limited resource is compounded by sharp disagreement in the scientific community over endangered species needs for in-stream flows. In this paper two game theory models are developed for addressing this resource management problem. Model I was designed as a second price sequential auction with repeat bidding and can be used for determining how much environmental water each state will provide and at what price. Model II was designed as a utility based multilateral bargaining model and can be used for determining how much water to allocate to environmental needs, given the supply costs from Model I. Empirical results are presented for Model I only. The results suggest that the use of game models can improve the prospects for reaching a resource management agreement. The willingness of states to supply environmental water is enhanced if the bargaining process is structured to disallow cheating and provide for political compensation.

Session 2-B. Integrating Physical and Socioeconomic Models

Integrated Modeling for Watershed Management—Multiple Objectives and Spatial Effects

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This paper describes a framework for analyzing the potential environmental and economic impacts of various watershed management strategies. We focus on management decisions that can change the extent and configuration of wetlands within a watershed. The framework is designed to aid decision makers in explicitly considering multiple environmental objectives for management decisions on a watershed scale. The modeling strategy consists of two phases. Phase 1 involves describing relationships between the extent and configuration of wetlands and other land use types in a watershed to the provision of different classes of valued ecosystem services. In Phase 2, the functions estimated in Phase 1 are incorporated into a spatial optimization model that allows comparisons of the expected environmental impacts and economic costs of various management strategies. In this paper we outline the general structure of the model, present some simulation results based on stylized production functions for ecosystem services, and discuss the potential utility of this strategy for watershed management.

Integrating Ecological, Hydrologic, and Economic Models for Water Valuation in South Texas

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An integrated modeling methodology is developed to analyze the viability of brush control for water yield in the Frio River basin, Texas. Ecological, hydrologic, and economic models are integrated to portray changes in forage production and water supply resulting from brush control, and to value supplemental water produced through brush control. Site-specific biophysical characteristics are used to simulate water yields from brush control across the watershed. Economic benefits from increased animal production for ranchers undertaking brush control are assessed. Benefits to Corpus Christi residential water consumers from ranchers' brush control activities are evaluated using the change in consumer surplus resulting from supplemental water produced through brush control. Results indicate an increase in water yield with brush control on 35% of the land area in the basin. However, the cost of brush control is more than the increase in returns it fosters on most range sites. Consumer surplus change for Corpus Christi residents over 25 years is zero under baseline conditions, implying subsidies for brush control in the Frio basin are not worthwhile at this time.

Integrating Ecological, Economic, and Social Goals in Restoration Decisionmaking

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A study is underway with the overall objective of refining and integrating spatially explicit models of watershed function and economic characterizations of restoration options with stakeholder-determined constraints and priorities. The resulting tool will assist stakeholders in identifying feasible restoration strategies and evaluate the ecological and economic effectiveness of these strategies at addressing watershed-level ecological, economic and social function. The study involves cooperation with two watershed councils representing diverse watershed types and disturbance levels to evaluate the effectiveness and transferability of the methodology between distinct ecological and economic systems. The analysis framework will apply design heuristics that embody ecological, economic and social constraints and preferences to allocate restoration activities to elements of the landscape to generate restoration options. It will then evaluate these options using ecological models of animal and plant species richness, composition, and abundance, population persistence, and water quality, and economic models estimating the cost and returns from the prescribed restoration activities. The success of the tool for addressing stakeholder needs and its impact on stakeholder decisionmaking is being explicitly evaluated using sociological and applied anthropological methods.

Distributed Modeling and Economic Analysis of Erosion in GIS for Watershed Restoration

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An integrated systems approach under development for watershed restoration in the Northwest Wheat and Range Region in the Pacific Northwest was described and applied to an example watershed in northern Idaho. Two constraints placed on model development are that input data is based on publicly available data sources, and that the models do not require calibration. Application of the current modeling approach to Lake Creek watershed shows that using these constraints provided very reasonable predictions on the hydrology and soil erosion. A very simple crop growth modeling approach based on actual evapotranspiration, provided by the hydrology model, and water use efficiency yielded reasonable, spatially distributed estimates of blue grass and wheat yields. Yield reductions after 75 years of soil erosion using the adjusted topsoil depths were somewhat low resulting in small yearly price reductions. The use of GIS and its spatial analytic capabilities in the example application shows the potential of the integrated systems approach to address the challenges associated with watershed restoration.

Session 3-A. Computer Decision Tools for Watershed Management

The Role of Problem Solving Environments in Watershed Assessment

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Effective watershed management requires that decision-makers receive input about, and balance consideration of, a number of competing factors. The fundamental drivers of watershed change are modifications to landuse and settlement patterns. To determine the effects of landuse and settlement changes properly requires, at a minimum, the ability to model effects related to surface and subsurface hydrology, economics, and biology. This means that an effective decision support system must integrate together several models. At the same time, the users of the system are likely to have diverse backgrounds and levels of expertise, and are certain not to be experts in all of the domains that must be modeled. Problem solving environments (PSE) seek to integrate multiple software tools into a single system for solving decision-making problems. This paper discusses the role that PSEs can and should play in future watershed modeling and management systems.

Integrated Decision Aid System for Watershed Management with Multicriteria Analysis and GIS

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General purpose decision support systems (DSS) for watershed management that fully integrate all necessary tools are still too complex or too costly to implement. However, we show, based on a brief analysis of the similarities between impact assessment and decision making frameworks, that functional requirements for a DSS can be separated in, on the one side, recurring tasks, common to most projects, and, on the other side, project specific tasks. We propose a core decision support system that integrates GIS and multicriteria functions accessible through a single interface to address the common requirements for a DSS. This core system can dock to existing databases an organization might have using the ODGI (*Open Geospatial Datastore Interface*) interconnectivity device. Project specific models (hydrological, erosion, etc.) compose the project-specific DSS extension and remain independent of the core DSS. The core DSS is designed to be user-friendly, links metadata with the data itself, and is Internet-enabled. GeoML's interface, metadata and multicriteria modules are now operational. These components have been successfully tested in a watershed study that consisted in ranking management alternatives based on environmental and economical criteria.

Interdisciplinary Watershed Analysis with GIS: The Watershed Characterization and Modeling System

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The Natural Resource Analysis Center at West Virginia University supports a multidisciplinary approach to watershed analysis and management. Geographic information system (GIS) capabilities have enabled the development of a set of tools for watershed characterization, modeling, and analysis that support decision making related to water quality problems. The tools are combined within a customized interface developed with ESRI's ArcView software to provide many hydrological modeling functions and decision support capabilities to both technical and non-technical users. Components of the current system, include: an overland flow model that provides insight into optimum water quality sampling locations, a flow estimation technique applicable to all streams in an identified area, an instream water quality and loading model for pollutant levels, and a watershed ranking model to prioritize where to focus remediation programs based on evaluation criteria for acid mine drainage affected areas. The primary goals of this system are to provide consistent technical information on natural processes and to help quantify benefits and costs of alternative actions. Such information is currently being used by the West Virginia Division of Environmental Protection to guide policy development and management decisions that address watershed and water quality problems.

A Graphic Modeling Tool for Negotiating Stakeholder Consensus in Policy Development

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In many areas of decisionmaking there has been a shift from a command and control focus toward a more consensus-based approach. As we begin to better understand that each watershed is unique, not only environmentally, but also socially, economically and politically, we also learn that there is an equally complex diversity of values between stakeholders who have an interest in these areas. The accurate assessment of values can effectively describe and explain individual and shared needs and the goals of stakeholders. The result of such an assessment would aid in planning for more sustainable land uses, whether these uses reflect the needs of urban, suburban or wildlife communities.

Environmental policy has evolved through this consensus process, but agreements remain difficult to achieve. Either by limiting choices available to stakeholders, or by assessing the results through filters that fail to capture the dynamics of the decision process, we continue to create unsustainable policies. This paper describes a previously unpublished graphic decisionmaking tool capable of anonymously representing the intensity of values held by individual stakeholders in policy decisionmaking. This model was created through 10 years of observation and participation in policy decisionmaking, and through interviews with participants in a wetland mitigation bank permit negotiation, that lasted over 5 years. This model is designed to aid consensus building in environmental policy.

Session 3-B. Managing/Restoring Urbanizing Watersheds

Framing of a Contingent Valuation Survey for Stream Biodiversity in Ohio

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Ecological risk assessment is an approach that has been used by the U.S. EPA for analyzing the likelihood of adverse effects on watershed endpoints (such as the Index of Biotic Integrity). The objective of the larger project described in this paper is to quantify the monetary values that stakeholders associate with biotic integrity. We frame the valuation in terms of ecological factors that change as residential development takes place. These include nutrient, sediment, and toxin inputs, and changing flow patterns. These factors, as well as economic and social factors, vary across four hypothetical development scenarios. We establish a methodology to link valuation of alternative development scenarios to associated changes in relevant ecological, economic, and social factors, and, in turn the likelihood of adverse effects on endpoints, such as the IBI. The models we use implicitly compare the costs of mitigating risk arising from residential development, as evaluated by a large sample of stakeholders, and can serve as tools that inform the public and decision-maker choices. The methodology brings together the characterization of physical and biological risks in a watershed so that contingent valuation methods can quantify the monetary value associated with biotic integrity endpoints.

Fiscal Consequences of Residential Development Patterns to Local Government

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Land extensive residential settlement patterns (development patterns characterized by separation between houses, development tracts, and existing economic centers) may have a number of adverse environmental consequences. Local governments can exercise significant regulatory authority on land use to influence how new population growth is settled spatially. Evidence from a literature synthesis is evaluated to examine the extent to which more land intensive forms of development are in the fiscal interests of local governments. The costs of providing many local government services are less sensitive to the spatial pattern of development than may be commonly presumed. Furthermore, more land intensive development may generate less revenue per capita than more land extensive development forms. On net, local governments do not appear to have strong financial interests to encourage land intensive forms of residential growth. Local governments may be willing to pursue policies that offer some water quality gains within land extensive forms of developments.

Integrating Science and Technology to Support Stream Naturalization near Chicago, Illinois

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Many urban and suburban communities in the Midwest are seeking to establish sustainable, morphologically and hydraulically varied, yet dynamically stable fluvial systems that are capable of supporting healthy, biologically diverse aquatic ecosystems - a process known as stream naturalization. This paper presents an integrated scientific and technological framework for stream naturalization in two human-dominated watersheds near Chicago, Illinois. The framework includes integration of social analysis, scientific research and technical guidance to match a community vision of environmental quality with technical and scientific realities.

The general goal of the projects described here is to establish a sound scientific and technological framework for stream naturalization via the integration of fundamental and applied research in fluvial geomorphology, aquatic ecology, hydraulic engineering and social theory. Scientific/technical support emphasizes the development and integration of predictive tools to evaluate the performance of possible naturalization designs at scales most appropriate to community-based projects. Social analysis focuses on place-based evaluations of how communities formulate an environmental vision and then, through decision-making, translating this vision into specific stream-naturalization strategies. Integration of the two components occurs in the context of community-based decision-making as the predictive tools are employed to help local communities translate their environmental visions into concrete environmental designs. Social analysis of this decision-making process reveals how the recursive interplay between the community's vision of what they want the watershed to become, and the scientific perspective on what the watershed can become to achieve the community's environmental goals, leads to the implementation of specific stream-naturalization practices.

Keeping the Big Apple Green: Integrated Water Resource Management for Central Park

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A comprehensive Water Quality Management Plan is being prepared for Central Park in New York City. This plan has three objectives: (1) ***improve water quality***, (2) ***conserve potable water***, and (3) ***reduce discharges from the Park to the combined sewer***. To accomplish these goals a series of structural and non-structural best management practices (BMPs) are being proposed. To evaluate the effectiveness of these plans, an integrated model system consisting of a geographic information system (GIS), an overland runoff model (SWMM), and a water quality model (WASP) was developed. The system demonstrates how these typically macro-scale tools can be combined to evaluate management decisions at the micro-

scale. Challenges and solutions for simulating the urban park environment, including obtaining large-scale mapping, determining hydrology, estimating pollutant loads, and quantifying maintenance measures within the models, will be discussed. Major findings of the study included: determination that algae production for the studied water bodies is nitrogen-limited, the current potable water feed is detrimental to water quality, sediment fluxes are a major contributor of nutrients to the water column, and structural BMPs would only provide marginal improvement in water quality. This project has demonstrated that as more large-scale data becomes available, and as we gain a better understanding of the environmental processes that occur within our water bodies and watersheds, we can continue to use our current tools (GIS, SWMM, and WASP) to evaluate management decisions for micro-scale areas.

Poster Session and Software Demonstrations

Digital Meadowlands: A Web-Based Decision Support System for an Urban, Estuarine Watershed

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The Hackensack Meadowlands District (District) is a 32-square mile degraded, urban, estuarine watershed, located six miles west of New York City. The Hackensack Meadowlands Development Commission (HMDC) is a state agency with comprehensive land use planning and permitting authority for the District. The Rutgers University Center for Information Management Integration and Connectivity in collaboration with the HMDC have developed a web-based system called "Digital Meadowlands" to access detailed information about the District in support of environmental management and research (http://cimic.rutgers.edu/digitalmeadowlands).

The application presently has five major modules each one with its own search engine and query procedures:
1) Image module with satellite images of the District;
2) Reports module with an electronic catalog of research and engineering reports that can be searched via a text-based query or by using an interactive map;
3) Monitoring data module with continually updated datasets on weather and air and water quality, and static datasets from discrete monitoring projects;
4) Interactive maps of zoning, parcel and land use; and
5) Videos of virtual fly-bys and TV news clips about the District.

Digital Meadowlands provides a wealth of information to scientists. With time it will become the repository of the collective environmental memory for the HMDC District. The staff from HMDC likely to benefit the most are those revising development proposals, drafting environmental impact forms, and involved in environmental impact studies, in outreach and in education. Short formal and hands on training sessions are being provided to staff on the use of the system.

Interactive Distributed Conservation Planning

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In the environmental/agriculture conservation planning process, more efficient and effective tools are needed for planners to assist private landowners with making wiser land use decisions. Current methods are slow, inefficient, and costly. Scientific techniques have not been fully implemented within the planning process, yet such plans are increasingly needed to meet water quality and TMDL requirements. The objectives of this study are to (a) utilize the web for accessing an **integrated science-based land use decision support system**; (b) link decision tools, models, and databases (to the user) via the web; (c) link distributed models and databases for enhanced planning efficiency; and, (d) integrate the above into an easily useable and readily accessible system. The procedures used involved utilizing focus groups input and planning expertise for the initial design. The system was developed in partnership with USDA/NRCS and several state agencies. A survey of 150 certified conservation planners (end users) was conducted to identify the data sets and needed planning tools. **Data, tools, and models** were then selected and integrated into a **web accessible system**. Specifically, the first generation used web interactive GIS that overlayed on digital orthoquads and/or soils polygons field boundaries, transportation, hydrologic features (drains, rivers, lakes, etc.), and high pesticide risk run-off or infiltration areas. Conservation planners found they could save time with the system (an operation that took 30 minutes could now be done within a few minutes). Clients could access the system quickly to help them with preparation for a meeting with their planner. Acquiring GIS maps in some cases in the past had been a lengthy process that limited use of the information in land use decisions.

Techniques for Assessing Pesticide Loading at the Watershed Scale

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Watersheds with drainage areas from 23,569 hectares to 40,404 hectares located in the White River Basin in Indiana, the Albemarle-Pamlico Basin in North Carolina and Virginia, and the Apalachicola-Chattahoochee-Flint Basin in Alabama, Georgia and Florida were chosen for Nonpoint Source Model (NPSM) simulations. Least squares regression of NPSM predicted flows versus USGS gauge data were 0.75, 0.44 and 0.69 for the calibration runs and 0.71, 0.69 and 0.64 for the validation runs in the Driftwood, Contentnea and Ichawaynochaway watersheds, respectively. Validation runs were performed for the period 1-1-1993 through 12-31-1995. Nash Sutcliffe coefficient values ranged from -0.66 to 0.45 for the calibration runs and 0.31 to 0.37 for the validation runs of NPSM. Spatially based models for the watersheds are also being created to provide a comparison of lumped and distributed parameter model predictions of sediment and pesticide loading. In the example given for the Ichawaynochaway HUC in the ACF basin, drainage density was found to be the most important predictor of in-stream suspended sediment concentration.

GIS Issues in Integrated Hydrologic, Economic, and Ecological Watershed Analysis

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Land development and urban sprawl bring with them a concern for surface water impacts, environmental quality, and infrastructure impacts. EPA's Watershed Approach has moved the emphasis from individual considerations to a holistic approach to watershed management. As more data become available in a digital format, the use of GIS integrated models to evaluate current and future conditions within a watershed is more prevalent. This research discusses the process of integrating models in the context of a prototype GIS data collection, derivation, and software development effort within the Upper Roanoke River Basin in Virginia. Specifically, this effort combines models for hydrology, economics, and fish health into a single, spatial modeling interface and confirms the utility of GIS approaches for watershed management. Besides being able to describe the physical landscape of the watershed, the GIS provides a common source of base data for all models, easily handles the data manipulations and calculations required by models, serves as a warehouse which communicates data and results among models, and provides a common interface for both inputs and display of model results. Issues of raster versus vector, spatial and temporal resolution are discussed.

Confined Animal Location and Manure Nutrients: Implications for Policy Targeting

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Using data from the Census of Agriculture on animal inventory and sales, we estimate county-level manure nutrient production on farms with confined livestock. Data from the National Resources Inventory are employed to convert county-based Census data to a watershed base. At the watershed level, vulnerability indices for manure nitrogen leaching and runoff and soil absorbed manure phosphorus runoff were developed to indicate potential priority watersheds for targeting manure management efforts in 1997. Our vulnerability indices are preliminary because they are a relative measure focused on recoverable manure nutrients. Recoverable manure nutrients are concentrated in watersheds in the South Atlantic-Gulf, Arkansas-White-Red, Upper Mississippi, and Missouri Basins. Watersheds in these basins, with the addition of the Mid-Atlantic Basin, contain most of the potential priority watersheds.

Economic Analysis of Water Use Strategies at Catchment Level with an Instream Flow Requirement

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A mathematical model of agricultural water use, a hydrological model, and economic simulation model were linked to quantify the economic and hydrological impact of deficit irrigation, increased water application efficiency and farm storage dams when maintaining an instream flow requirement (IFR) under stochastic water supply conditions. The main finding was that a water conservation policy aimed at reducing the amount of water withdrawn from the river could bring more pressure to bear on stream flow. Water can only be saved if consumptive use is reduced. Increased water application efficiency is detrimental to other users as a result of reduced return flow. The economic cost of maintaining a specific IFR increases with the use of all three strategies as the probability of maintaining the IFR increases. Because of the control that can be exercised over the supply of water, a farm storage dam is the best strategy for minimising the costs for irrigators. The interaction between water legislation, water policy administration, technology, hydrology and human value systems necessitates an integrated approach to facilitate water management at catchment level and to formulate policies that will be in the interest of society.

Economic Impact of Reservoir Water Level Changes

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Wise interbasin management of southeast U.S. water resources is important for future development. Alabama-Coosa-Tallapoosa and Apalachicola-Flint-Chattahoochee River basins' water usage has evolved from power generation to diverse multiple uses. Recreation and housing have become increasingly valuable components. Changing use patterns imply changing resource values. This study focused on six Alabama reservoirs, using contingent valuation questions in on-site, telephone and mail surveys to estimate changes in lakefront property values, recreational use expenditures, and preservation values for scenarios of alternative water level management.

As summer full-pool duration was decreased, lakefront property value decreased and as duration increased property values increased, but at a lesser absolute rate. Similar findings occurred for winter drawdown alternatives. Permanent 0.3 meter (one-foot) reductions in summer full-pool water level resulted in a 4% to 15% decrease in lakefront property values. Recreational expenditures decreased by 4% to 30% for each 0.3 meter (one-foot) lowering of reservoir water levels. Current non-users of the six reservoirs showed strong preferences for protecting the study reservoirs with willingness to pay values of $47.21 per household or approximately $29 million for the entire watershed basin area.

Resource management based on historic use patterns may be inappropriate. Developed valuation methodologies could be used for timely reevaluation of reservoir resources.

Water Quality Impacts of Conservation Agricultural Practices in the Mississippi Delta

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Nonpoint pollution generated by conventional agricultural practices is one of the major sources of environmental problems associated with agricultural production. Agricultural conservation practices including no-tillage operation have been introduced as alternatives to cope with such challenges. This study attempts to examine the economic and the environmental impacts of no-tillage as compared to conventional agricultural practices of cotton, soybeans and corn in the Mississippi Delta. The impacts at both farm and watershed levels are investigated, using the Erosion Productivity Impact Calculator (EPIC).

Development of Information to Guide Salmon Stock Rebuilding in Clayoquot Sound

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Clayoquot Sound, on the west coast of Vancouver Island, has become an international icon in the debate about the impacts of forest harvesting practices on some of the last intact coastal rainforests of North America. A host of community and government based initiatives are imposing unprecedented change on land use management in Clayoquot Sound as part of a new approach to sustainable resource use. The Kennedy Watershed of Clayoquot Sound has a long history of resource extraction and a much shorter history of examining the state of resources and reinvestment into planning, management and in some cases rehabilitation of degraded resource values. We present components of the Kennedy watershed habitat and salmon atlas to illustrate: (a) our understanding of historic resource exploitation trends and the present status of forests, water, salmon and salmon habitat resources; (b) watershed analysis tools used to understand resource histories over space and time and assist with prioritizing rebuilding and restoration initiatives for salmon stock and habitat among sub basins in the watershed; and (c) approaches used to help facilitate the involvement of a diversity of stakeholders from industry, government and community groups in examining and resolving land use and resource management issues that frequently arise in B.C. watersheds.

Map-based Stream Narratives to Facilitate Stakeholder Involvement in Watershed Management

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Watershed stewardship activities throughout North America have evolved into a process that requires more involvement in planning and decision-making by community stakeholders. Active involvement of all stakeholders in the process of watershed stewardship is dependent on effective exchange of information among participants, and active involvement of a wide range of stakeholders from "communities of place" as well as those from "communities of interest." We developed a map-based stream narrative tool as a means to (a) assemble a wealth of incompletely documented, "traditional" ecological or natural history observations for the rivers or streams, and (b) to promote a higher level of active involvement by community stakeholders in contributing to information-based, watershed management. Creation of stream narratives is intended for use as a tool to actively engage local stakeholders in the development of a more comprehensive information system to improve management for multiple stewardship objectives in watersheds. Completion of map-based stream narrative atlases provides a valuable supplement to other independent efforts to assemble observations and knowledge about land-based natural resources covering entire watersheds. We are confident that completion of stream narrative projects will make a valuable addition to the information and decision making tools that are currently available to the public and resource agencies interested in advancing the cause of community-based approaches to watershed and ecosystem management.

A GIS Decision Support Tool for Animal Facility Permitting and Nutrient Management

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The Earth Sciences and Resources Institute at the University of South Carolina (ESRI-USC) is working with the U.S. Department of Agriculture's Natural Resources Conservation Service in South Carolina to integrate water quality and animal waste management programs through the use of a Geographical Information System (GIS)–based Decision Support System. The Decision Support System recognizes and goes beyond regulatory requirements to site animal feeding operations and related waste application based on environmental and watershed-related data. Version 1 was completed at the end of 1999 and piloted in Marion County, South Carolina while version 2, developed 2000, included Marlboro County, South Carolina. Field-testing in these two counties for the siting of animal feeding operations and the development of waste management plans was underway in the latter half of 2000. As the area of application of the Decision Support System increases to five additional counties in the Great Pee Dee and Little Pee Dee River watersheds, data assimilation and combination across county borders will become an

increasingly important issue. ESRI-USC is exploring ways of using internet-based GIS technology to address distributed GIS information problems.

A Decision Support Tool for the Management of Multireservoir Systems

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A decision support tool is developed for the management of water resources, focusing on multipurpose reservoir systems. This software tool has been designed in such a way that it can be suitable to hydrosystems with multiple and very often contradictory water uses and operating goals, calculating complex multi-reservoir systems as a whole. The mathematical framework is based on the original scheme parameterization-simulation-optimization. The main idea consists of a parametric formulation of the operating rules for reservoirs and other projects (i.e. hydropower plants). This methodology enables the decrease of the decision variables, making feasible the location of the optimal management policy, which maximizes the system yield and the overall operational benefit and minimizes the risk for the management decisions. The program was developed using advanced software engineering techniques. As proved two detailed case studies, it is flexible enough and thus suitable for use to a wide range of applications, so it can be helpful to water and power supply companies and related authorities.

Incorporation of HSPF into a Problem Solving Environment for Watershed Management

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This paper describes the integration of a comprehensive hydrological model known as the Hydrological Simulation Program Fortran (HSPF) into a *problem-solving environment* (PSE) for watershed management. The original PSE concept was a structure providing web-based access to a suite of models, including HSPF and other models of in-stream hydrodynamics, biological impacts and economic effects, for the watershed-wide assessment of alternative land use scenarios. The present paper describes only the HSPF integration into the PSE program. Example applications to the 148 square kilometer (57 square mile) Back Creek sub-watershed in the upper Roanoke River system (1479 square kilometers or 571 square miles) in southwest Virginia are used to illustrate important concepts and linkages between land development and hydrological change. The features of HSPF and its limitations in this context are fully discussed. The paper as such is a proof-of concept paper and not a completion report. There are important additions to the present work currently in-progress that will add substance to the critical linkage between land use change and in-stream impacts on fish community, macroinvertebrates, and aquatic habitat.

Integrating Phosphorus and Nitrogen Decision Management at Watershed Scales

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The persistence of water quality problems has directed attention towards the reduction of agricultural non-point sources of phosphorus (P) and nitrogen (N). We assessed the practical impact of three management scenarios to reduce P and N losses from a mixed land use watershed in central Pennsylvania, USA. Using an agronomic soil P threshold of 100 mg Mehlich-3 P kg^{-1}, above which no crop response is expected, 80% of our watershed would receive no P as fertilizer or manure. An environmental soil P threshold of 195 mg Mehlich-3 P kg^{-1}, above which the loss of P in surface runoff and subsurface drainage increases greatly, restricts future P inputs in only 40% of the watershed. Finally, P and N indices that account for likely source and transport risks were imposed and showed that 20% of the watershed was at high risk or greater of P loss, while 60% of the watershed was classified as of high risk of nitrate (NO_3) leaching. Areas at risk of P loss were near the stream channel, while areas at risk of NO_3 leaching were near the boundaries of the watershed, where freely draining soils and high manure and fertilizer N applications coincide. Remedial measures to minimize P export should focus on critical source areas, while remedial measures to reduce N losses should be source based, concentrating on more efficient use of N by crops.

Negotiating Science and Values with Stakeholders in the Illinois River Basin

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Current research in the Illinois River Basin is designed to develop and test a policy formulation protocol that will foster watershed management policy that is technically effective, economically efficient, administratively feasible, and sociopolitically acceptable. This paper describes the results of the initial baseline impact assessment that includes social, economic, biological, and physical systems as well as the development of a computer visualization platform that will be used as a decision support tool to conduct policy maker and stakeholder negotiation workshops. Numerically modeled and visually simulated environmental impacts serve as the basis for developing several policy maker scenarios for prospective watershed management policies. These scenarios, which will be subject to stakeholder review and negotiation, will undergo iterative review and amendment by policy makers and stakeholder groups until a consensus watershed management policy is adopted. Preliminary results from the baseline social impact assessment indicate that such a consensus is obtainable.

Landscape Approach to Watershed Assessment and Management: San Pedro and Catskill/Delaware Studies

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Significant land cover changes have occurred in the watershed contributing runoff to the upper San Pedro River in Sonora, Mexico and Southeast Arizona. These changes, observed using a series of remotely sensed images taken in the 1970's, 1980's and 1990's, have been implicated in the alteration of the basin hydrologic response. The Cannonsville subwatershed, located in the Catskill/Delaware watershed complex that delivers water to New York City, provides a contrast in land cover change; in this region the watershed condition has improved over a comparable time period. A landscape assessment tool using a geographic information system (GIS) has been developed that automates the parameterization of the Soil Water Assessment Tool (SWAT) and KINEmatic Runoff and EROSion (KINEROS) hydrologic models. This tool was used to prepare parameter input files for the San Pedro Basin, a subwatershed within the San Pedro undergoing significant changes, and the Cannonsville watershed using historical land cover data. Runoff and sediment yield were simulated using these models. In the Cannonsville watershed, land cover change had a beneficial impact on modeled watershed response due to the transition from agriculture to forest land cover. Simulation results for the San Pedro indicate that increasing urban and agricultural areas and the correlative decline of grasslands resulted in increased annual and event runoff volumes, flashier flood response, and decreased water quality due to sediment loading. These results demonstrate the usefulness of integrating remote sensing and distributed hydrologic models through the use of GIS for assessing watershed condition and the relative impacts of land cover transitions on hydrologic response.

Integrated Information Systems for Integrated Decisions: Watershed Management in Sudan

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Decision-makers in the water system in Sudan adopt some supply and demand oriented measures to manage water resources. While their focus continued to be on the infrastructures of the distribution system, a wide range of demand oriented measures are in action. However, the escalation of water-related problems encouraged the government to prioritize “the involvement of stakeholders in a decentralized context” over other issues. Within this context, a wide range of information systems has been used. The effectiveness of these tools is being challenged by the lack of the appropriate organizational sets, the multiplicity of decision data and variables and the focus on integrating the water system with other systems at the expense of integrating decisions upstream and down stream within the water system. This

has complicated the management process, increased the costs of information infrastructure and defeated the efforts of decentralization and stakeholders involvement.

Knowledge-based Decision Support for Watershed Assessment

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The Clean Water Act requires States to develop lists of waters that do not meet water quality standards even after point sources of pollution have installed required levels of pollution control technology. States must develop total maximum daily loads (TMDLs) for listed waters. Conventional TMDL development is carried out on individual streams by analyzing impaired conditions segment by segment. This approach does not 1) address the spatial and temporal scales required to establish adequate reference conditions for water quality parameters, 2) estimate the predictive capabilities of scale relations for spatially continuous ecoregions, 3) project likely scenarios of water quality change due to changes in land use, cover, or climate, or, 4) relate monitoring technologies and standards to defined ecoregional scales. About 35,000 individual water bodies in the US will require TMDL determinations in the next few years. To be effective these must address the incremental effects of human activities and ecological processes within the watershed. Many regulatory and land management agencies are now promoting the concept of watershed analysis as the appropriate scale for assessments. However, there are few tools to assist managers in the decision making process that follows data gathering. The Environmental Management Decision Support (EMDS) system was developed as a tool to allow these analyses to take place on an entire watershed thereby accelerating the completion of TMDLs for listed waters.

Designing a Multi-credit Trading System Using Watersheds as a Basis for Trade

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A sound Watershed Stewardship Action Strategy (WSAS) is a step-by-step process, which will help government organizations, and private companies develop a pollutant trading system incentizing ecosystem restoration and water quality improvement. WASA is critical to a state and regional long-term goal for economic success, protection of public health, improved water quality, and for meeting TMDL regulations. It also promotes stakeholder involvement, education, training and buy-in to the future needs of watershed protection and economic development. The objective of a Watershed Stewardship Action Strategy is to develop a process which will allow these goals to be met.

A major obstacle for TMDL implementation is that no process and tools currently exist. Finding the best solution to the TMDL challenge requires a series of linked decisions that can be classified within the six steps of the WSAS. The process systematically guides decision-makers and stakeholders through these decisions and recognizes that good decisions require a balance of analytical support and participant facilitation and buy-in. Each step involves several important decisions and requires analytical models or other tools to ensure an objective analysis and valid conclusions.

This effort is designed to help develop a national model for multi-media pollution trading. This includes incentive based approaches using trading models for wetlands, carbon sequestration, nutrient and total suspended solids and temperature TMDls as well as hunting and other forms of recreational use.

From Landscapes to Waterscapes: A PSE for Landuse Change Analysis

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We describe the design and implementation of L2W - a problem-solving environment (PSE) for landuse change analysis. L2W organizes and unifies the diverse collection of software typically associated with ecosystem models (hydrological, economic, and biological). It provides a web-based interface for potential watershed managers and other users to explore meaningful alternative land development and management scenarios and view their hydrological, ecological, and economic impacts. A prototype implementation for the Upper Roanoke River Watershed in Southwest Virginia, USA is described.

A Distributed Integrated Decision Support System for Watershed Policy Analysis

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To provide agricultural policy decision-makers with a policy analysis tool for watershed assessment, we developed a tool that allows independent computer modules to be run in a coordinated way to solve a complex agricultural policy decision. This paper describes the integration scheme and the tools we used to link otherwise independent modules through the Internet into a single decision support system. We also describe the individual modules we have developed to define and assess the impacts of agricultural policies in a watershed, and we describe a simple test of the integration environment with highly simplified versions of the full modules.

Generating Farm Descriptions in a Watershed from Incomplete Data Using Simulated Annealing

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Simulated annealing provides an appropriate way to generate needed specific descriptions of the distribution and spatial location of agricultural resources within a watershed based on incomplete information. Compared to manual methods using GIS-based analysis and including data from aerial photography, the simulated annealing method described here is more likely to generate realistic spatial characterizations of the distribution of agricultural resources and practices in a watershed. Also compared to the manual method, the annealing process is considerably more efficient and can be more easily accommodate multiple criteria (constraints) and modifications to those criteria. However, a manual method based on an initial spatial clustering algorithm did better at creating farms with contiguous fields.

Conjunctive Surface and Ground Water Management in the Jakarta Region, Indonesia

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This study investigates the degree of **economic inefficiency** of the current institutional arrangements for **surface and ground water management** in meeting urban water demand in the Jakarta region of Indonesia. A model of integrated surface and ground water management is developed using **GAMS** (General Algebraic Modeling System) software. The model maximizes the present value of net social benefits from piped water and groundwater consumption across all users over time from 1999 to 2025. Four policy scenarios are examined: the status quo, the social planner's solution and two groundwater pumping quota scenarios: the aggregate and partial groundwater pumping quota. Three variations in each policy scenario are considered: investment in water infrastructure of the Jakarta water enterprise, economic growth and discount rates.

The status quo, depending on the investment option, economic growth and the discount rate, results in a 7.4 to 47.8% loss in economic efficiency relative to the social planner's solution. The partial quota is the most feasible, applicable and manageable scenario. The optimal investment option could increase the volume of piped water supply and reduce the cost of water production. The volume of water delivery could increase by up to 156%, but it implies only a 35% increase in the surface raw water demands above the current level. However, this scenario does not significantly reduce cumulative groundwater extraction over the time period considered.

Holistic Watershed Approach Protocol for Integrated Watershed Characterizations

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Integrated watershed characterizations produce better environmental data to make more informed decisions about where and how we invest our resources toward watershed management of point source and nonpoint source pollution problems. Involving local, state, and federal agencies; industry; academia; and the public in planning and sampling for watershed characterizations, leads to effective protection, restoration, and enhancement of the ecological integrity of water quality and quantity. Why…because everyone is part of the process. Time, costs, knowledge, skills, and abilities are some of the limiting factors when attempting to perform these tasks separately for the desired ecological integrity. Inconsistencies in planning, sampling, and data collection methodologies create quality assurance and quality control concerns. A standard operating procedure, or protocol, eliminates these inconsistencies. Implementation of a protocol, in an integrated fashion, reduces limitations and promotes outreach, education, and training, as well as improves knowledge, skills, and abilities. The West Virginia Division of Environmental Protection's Stream Restoration Group currently implements a **Holistic Watershed Approach Protocol** involving diverse stakeholders in planning and sampling for integrated watershed characterizations in five of West Virginia's thirty-two hydrologic regions. This **Protocol** is a dynamic document continually evolving to accommodate multiple applications and satisfy specific needs of diverse stakeholders.

Assessing Nitrogen and Phosphorus Loadings from Agriculture in the Chesapeake Bay Watershed

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This study, utilizing farm level agricultural census data, identifies a 12 percent reduction in farms and a 9.4 percent decline in cropland across the Chesapeake Bay watershed during the 15-year period, 1982 through 1997. The number of farms with livestock decreased by 26 percent during this same period and the cropland area in livestock farms declined by 9 percent. Total animal units remained relatively constant at approximately 4 million. However, the mix has shifted. Although milk cows continue to make up the largest segment of confined animal units in the watershed, the number of milk cow animal units decreased by 9.8 from 1982 to 1997. The percentage of poultry animal units during this same period increased by 11.1 percent. The amount of recoverable manure nitrogen produced in the watershed increased by 17 percent as a result of the changing proportion of the type of animal units in the mix.

Watershed scale estimates of the amount of nitrogen available from the purchase of commercial fertilizer and land-applied animal manure did not exceed the estimated crop uptake of nitrogen for 1982 through 1997. However, county scale estimates indicate the potential for nitrogen in excess of crop uptake in a minimum of 7 counties in 1997. The potential nitrogen from manure available for volatilization at the watershed scale was estimated at 166,100 t (366.1 million pounds).

At the watershed scale, the estimated 113,375 t (250 million pounds) of phosphorus available from recoverable manure and commercial fertilizer in 1997 exceeded crop uptake by 87 percent. Phosphorus from recoverable manure made up 44 percent of the total available phosphorus in 1997. The amount of phosphorus available from manure increased by 21.7 percent from 1982 to 1997. As with nitrogen, changes in the proportion of animal types in the mix of animal units had a very direct effect on the amount of phosphorus available. The proportion, of the total recoverable manure phosphorus from poultry increased from 52 percent in 1982 to 64.7 percent in 1997. County scale estimates suggest a minimum of 24 counties with phosphorus from manure in excess of crop uptake. The estimated excess was 18,412 t (40.6 million pounds).

Decision Support System for Catawba River Basin

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WARMF (Watershed Analysis Risk Management Framework) was developed as a decision support system for the entire 12,330 km^2 (~5,000 $mile^2$) Catawba River Basin of North and South Carolina. The watershed is divided into a network of land catchments, stream segments, and stratified lakes. WARMF applies daily meteorology data to land catchments to simulate runoff and nonpoint loads. The nonpoint loads are routed together with point source loads to predict water quality in rivers and lakes. WARMF provides step-by-step roadmaps for calculating TMDLs and consensus building. In each step, WARMF supplies pertinent scientific data for the stakeholders to make incremental decisions. The scientific data may include spatial distributions of point and nonpoint loads, hydrology and water quality of river segments, and water quality profiles of lakes, all displayed in GIS maps. In addition, the cost/benefit of pollution trading, stakeholders' alternative rankings, and the nominal scores of rankings are provided for the stakeholders to determine possible compromises for consensus. Due to a lack of infrastructure to implement a bi-state consensus process involving many stakeholders with diverse priorities, WARMF is currently being applied on a subwatershed scale with a smaller stakeholder group in the Muddy Creek region. WARMF will continue to be used on a basinwide scale to integrate the cumulative impacts of improvements made in subwatershed areas.

Session 4-A. Watershed Assessment and Priority Setting

Targeting Nonpoint Source Pollution Control: Phosphorus in the Minnesota River Basin

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The state of Minnesota seeks to reduce phosphorus loading to the Minnesota River by 40% from current levels. Looking at one major watershed in the river basin, we examined the cost-effectiveness of targeting versus not targeting specific practices or regions within a watershed for controlling nonpoint phosphorus pollution from agriculture. Integrating biophysical simulation results from current and alternative production practices with production cost and return estimates enabled us to analyze this policy. Our results indicated it is more cost effective to reduce nonpoint pollution by targeting particular regions or practices in a watershed compared to not targeting. Specifically, producers farming on cropland susceptible to erosion in close proximity to water who switch from conventional tillage to conservation tillage and reduce phosphorus fertilization levels to those recommended by the state extension service will appreciably reduce phosphorus nonpoint pollution loading potential. Efforts to target those producers could reduce potential transaction costs and compensation from "takings" by approximately $50 million over not targeting.

Biological and Economic Implications of Sacramento Watershed Management Options

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We bring together spatially- and temporally- explicit mechanistic models of hydrodynamic, water quality, and ecological processes with an economic model to examine water management alternatives for California's Sacramento River and Delta ecosystem, a large-scale watershed. Overallocated water supplies in most years, combined with increasing demand for water for environmental purposes, have created a politically charged atmosphere and a need for quantitative assessment of the implications of policy alternatives. By developing and analyzing a common set of policy scenarios, this integrated framework allows us to consider tradeoffs between agricultural economic factors and population dynamics for two at-risk fish species. We analyze two rather extreme types of policy options; one involves structural modifications to change the flow of water within the watershed, but no change in water diversions, while the other reallocates water from agricultural users to fish and wildlife. Results suggest that substantial environmental improvements could be made at a relatively modest cost to farmers (1-4 percent reductions in revenues), but that those costs could be significant locally. In addition to tradeoffs between farmers and environmental interests, results suggest that policy makers may need to balance competing environmental objectives.

Using Maryland's Stream Corridor Assessment Survey to Prioritize Watershed Restoration

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The Stream Corridor Assessment survey has been developed by the Maryland Department of Natural Resources as a watershed management tool to both identify environmental problems and prioritize restoration opportunities on a watershed basis. Potential environmental problems commonly identified during the survey include: channel alterations stream sections, excessive bank erosion, exposed pipes, inadequate stream buffers, fish migration blockages, trash dumping sites, near stream construction, pipe outfalls and unusual conditions. In addition, the survey records information on the location of potential wetlands creation sites and collects data on the general condition of in-stream and riparian habitats. Over the past several years working with the Maryland Conservation Corp, watershed associations and local governments more than 1760 km (1094 miles) of Maryland streams have been surveyed. Overall, the survey has proven to be a cost effective starting point for many watershed restoration efforts and the results of the survey have been used to target over a million dollars of restoration work so far.

Sediment Oxygen Demand Impacts on Dissolved Oxygen TMDLs in the Arroyo Colorado River

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The Arroyo Colorado River is the principal source of fresh water inflow to the Southern Laguna Madre, an economically and ecologically important resource for the Lower Rio Grande Valley region of Texas. The Arroyo Colorado serves as a principal drainage system for municipal waste treatment effluent (from the cities of Harlingen and McAllen, Texas), agricultural production runoff, and stormwater runoff from the Lower Rio Grande Valley. The lower reaches of the Arroyo Colorado have historically failed to meet their use under subsection 303(b) of the US-Clean Water Act (CWA) due to fecal coliform bacteria and low dissolved oxygen (DO). Sections of the Arroyo Colorado were listed in the 1998 CWA 303(d) report of non-compliant water bodies resulting in an attempt by the Texas Natural Resource Conservation Commission to develop a Total Maximum Daily Load (TMDL) allocation for oxygen-demanding substances. We investigated *in situ* sediment oxygen demand (SOD) processes to determine if SOD was a major source of DO depletion in the river. In some reaches of the Arroyo Colorado River, SOD accounted for as much as 97% of the total oxygen depletion from the lower third of the water column, making SOD a critical element in TMDL allocations for low DO.

Session 4-B. Watershed Planning and Decision Making

New Federal Support for Priority Watershed Management Needs

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The 1996 Farm Bill, 1998 Clean Water Action Plan, 1999 Unified National Strategy for Animal Feeding Operations, and other initiatives have increased the level of support that federal agencies give to watershed management and have targeted resources to priority watersheds, including watersheds impacted by agricultural activities. The Farm Bill assigned the U.S. Department of Agriculture (USDA) a major role in local watershed programs. USDA involves farmers in watershed programs and provides cost share and incentive payments for nutrient planning, riparian protection, and other practices prioritized to most efficiently achieve watershed goals. As a result, USDA has become a funding source for environmental initiatives targeted to watersheds, as well as a technical resource that attempts to support more efficient use of Federal and State environmental expenditures. Given the scarcity of resources and the barriers to targeting either Federal or State expenditures, USDA's focus on efficient remedies may contribute to everyone's success. The new Federal policies can lead to more effective voluntary programs and potentially influence the evolution of U.S. environmental programs in rural watersheds.

A Values Framework for Watershed Decision-Making

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This paper outlines the history of water resources institutions and decision-making in the United States and describes the current trend towards a collaborative watershed decision-making process and its democratic and community-based elements. A framework of value systems and decision criteria is presented for assisting communities in the identification of community values and design of watershed decision-making procedures. Today's collaborative watershed decision-making process needs a more detailed accounting system for values so that watershed communities can more easily and precisely consider the sources of problems, the trade-offs among alternative solutions, and the issues of who will benefit and who should pay. Value systems are described for ethics, politics, markets, and science. Criteria for good decisions are presented and discussed in terms of collaboration, level of detail and problem complexity. In concluding remarks, the uses of value systems are discussed in the design of community-based watershed decision-making procedures. As watershed problems and solutions become more complex, the success of the collaborative approach will greatly depend on the ability of communities to understand and integrate a greater variety of values into their decisions.

Creating Stakeholder Involvement in Watershed Planning in Pierce County, Washington

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Pierce County, Washington has prepared three watershed action plans and is in the process of completing a fourth. Combined, the planning areas include three counties, three Indian tribes, 24 cities and towns, Fort Lewis, McChord Air Force Base, Mount Rainier National Park, national forest land, the Port of Tacoma, and about 600,000 residents. Under these conditions, generating agreement between stakeholders on issues related to water could easily be seen as arduous if not unattainable.

In order to complete this task, watershed planning for nonpoint sources of pollution in Pierce County watersheds involved a variety of participatory methods. The intention of the program was to engage diverse groups of stakeholders in generating solutions to nonpoint sources of water pollution. We addressed issues such as forest practices, boats and marinas, agriculture, on-site sewage disposal systems, stormwater and erosion, and other sources of water pollution using methods that fully engaged all participants and facilitated agreement. We found that the appropriate use of decision-making tools built trust, maximized participation, facilitated learning, encouraged creativity, developed working relationships, shortened the time frame for the process, and increased the level of commitment participants had to implementing the plans.

Achieving NPS Pollution Reduction Goals for Large Watershed: Shenandoah Potomac River, Virginia

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As part of the Chesapeake Bay Program, the Commonwealth of Virginia undertook an ambitious, three-year, $20 million, effort to reduce by 40% nutrient nonpoint source (NPS) pollution to the Shenandoah and Potomac Rivers. This meant intensifying nonpoint source pollution control programs ten-fold. The strategies employed demonstrated that a watershed with concentrated agricultural operations, as well as densely populated urbanized areas, could rely upon greatly expanded, traditional nonpoint source pollution control programs to reach critical goals. A successful nonpoint source control project of this magnitude suggests management approaches useful to other watershed projects. There are few, if any, instances in which a sizeable nonpoint source pollution control strategy has been implemented in such an accelerated framework, making this experience with the Shenandoah Potomac Rivers relevant to others pursuing a watershed approach to NPS prevention.

Session 5-A. Modeling Issues

Integrating Humans in Ecosystem Management Using Multi-Criteria Decision Making

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The Ecosystem Management (EM) process belongs to the category of Multi-Criteria Decision Making (MCDM) problems. It requires appropriate decision support systems (DSS) where "all interested people" would be involved in the decision-making process. Critical environmental values to EM, such as biological diversity, health, productivity and sustainability, have to be studied, and play an important role in modeling the ecosystem functions, but also human values and preferences influence the decision making. Public participation in decision and policy making is one of the elements that differentiate EM from the traditional methods of management. Here a methodology is presented on how to quantify human preferences in EM decision making. The case study of the National Park of River Nestos Delta and Lakes Vistonida and Ismarida in Greece is presented as an application of this methodology, which shows that the direct involvement of the public, the quantification of its preferences and the decision-maker's (DM's) attitude provide a strong tool to the EM decision-making process. Public preferences have been given certain weights and three MCDM methods, namely, the Expected Utility Method, Compromise Programming and the Analytic Hierarchy Process have been used in order to select alternative management solutions that lead to the best configuration of the ecosystem and are also socially accepted.

Assessing Changes in Watershed Flow Regimes with Spatially Explicit Hydraulic Models

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Urbanization, farming, and other watershed activities can significantly alter storm hydrographs and sediment erosion rates within a watershed. These changes routinely cause severe economic and ecological problems manifested in the form of increased flooding, and significant changes in channel morphology. As the activities within a watershed influence the hydrologic, hydraulic, and ecological conditions within a river, interdisciplinary approaches to predict and assess the impacts that different land uses have on streams need to be developed. An important component of this process is ascertaining how hydrologic changes induced by specific watershed activities will affect hydraulic conditions and the concomitant flood levels, sediment transport rates, and habitat conditions within a stream. A conceptual model for using spatially explicit (two-dimensional) hydraulic models to help evaluate the impacts that change in flow regime might have on a river is presented. This framework proposes that reproducing and quantifying flow complexity allows one to compare the hydraulic conditions within urban, urbanizing, and non-urban streams in a more biologically and economically meaningful way. The justification, advantages, and need for such methods are argued through the results of one- and two-dimensional hydraulic model studies. How this methodology can be implemented in watershed urbanization studies is described.

An Integrated Approach – Polecat Creek Water Quality Monitoring Project

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An assessment of the Chesapeake Bay Preservation Act is being made at the Polecat Creek watershed through an integrated approach involving hydrologists, biologists, and hydro-geologists. The program involves long-term monitoring of physical and chemical parameters of surface and ground waters, biological status, and the changes in land use/land cover of the watershed. The surface water parameters being monitored include stream flow, nutrients, sediment, and bacteria. Biological communities being assessed include benthic macroinvertebrate and fish community structures. The groundwater is monitored in agricultural/forested and residential areas in Piedmont and Coastal Plains. The nutrient data (1994-99) at the watershed outlet indicate that except for TSS and TP, there were no significant differences in nutrient concentrations. The nitrate and phosphorus concentrations were below the EPA's limits for drinking water. The pooled IBI scores indicated a decline in maximum and minimum IBI values; however there was no trend observed in the median values. With few exceptions, ammonia concentrations in groundwater were less 0.05 mg/L as N in the residential transect. The nitrite plus nitrate levels at the forested site in the Coastal Plain were similar to those in the Piedmont area, but concentrations at the Coastal Plain agricultural site were more variable. The results of this study will enable managers and planners to make sound land management decisions to protect water quality and aquatic resources from the nonpoint source pollution

Session 5-B. Policies and Institutions for Watershed Management

Evaluating Policy Alternatives for Effective and Equitable Watershed Management

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Targeting of pollution control practices among farms has been shown to increase cost effectiveness of expenditures. Targeting may be impeded by concerns that costs are inequitably distributed. The cost effectiveness and equity of targeted and uniform allocation of buffers were evaluated on nine simulated farms in Virginia. Costs of buffer installation were estimated using a farm linear programming model. Equity of costs was evaluated under three definitions of equity: all farms share equally in costs; farms pay in proportion to their pollution potential, and farms pay in proportion to their land area.

Targeting of buffers to fields adjacent to blue-line streams where cost effectiveness is greatest can lower farmers' costs by over one third compared to uniform allocation. The targeted scenario was less equitable

under all three definitions of equity, but the difference in the equity measure was less than 10 percent for two of three equity definitions.

While further research is needed, these results may imply that equity is not necessarily a barrier to targeting water quality practices based on cost effectiveness. Depending on the equity definition, targeting may be almost as equitable as uniform application of regulations. Further research is needed to determine which definition of equity has greatest acceptance among watershed stakeholders.

The Structure of U.S. Markets for Water-Quality Trading

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The use of transferable discharge permits in water pollution, what we will call water quality trading (WQT), is rapidly growing in the U.S. This paper reviews the current status of WQT nationally and discusses the forms that such markets can take. Four main structures are observed: exchanges, bilateral negotiations, clearinghouses, and sole-source offsets. While exchanges offer the potential to be very fluid markets with low transaction costs, they can only function if a high degree of uniformity can be achieved, uniformity that is difficult to satisfy in water quality markets. Bilateral negotiations, in contrast, are appropriate when there is a high level of diversity in credits but have the disadvantage of very high transaction costs. Clearinghouses, in which a governmental or non-governmental body acts as an intermediary between buyers and sellers, can reduce transaction costs but might be able to accommodate a higher level of credit diversity. Finally, sole-source abatement structures do not involve trading at all, but instead represent a cost-reducing alternative to command-and-control regulations. No one structure is optimal for all scenarios. Hence, we expect that a diversity of WQT structures will persist over time.

Watershed Management and Policy in Hawaii: Coming Full Circle

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Changes in watershed management and policy in Hawai‘i are an instructive case study on the evolution of resource management from a traditional, vertically integrated system, to a segmented central government-based system, and now towards a community and watershed focus. The rise of European social and economic influences coupled with the precipitous decline in the Hawaiian population in the years following European contact led to the destruction of traditional management structures. Subsequently, the dominance of outside interests in Hawai‘i society and politics, culminating with the sugar industry, facilitated the unrestricted use and subsequent privatization of land and water resources. The post-WWII era ushered in fundamental changes in Hawai`i society and politics including renewed appreciation of traditional management practices. Government policies, increased community interest in resource

management, and a renaissance in Hawaiian culture have converged in recent years to facilitate the development of new management structures that draw on both traditional and contemporary management. These structures hold great promise for improving Hawaiian watershed management. Our observations suggest that other jurisdictions may find it productive to examine traditional management and policy structures and try to relate them to contemporary community-based resource management policies and activities.