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Watershed '96

Contents - Sessions 1-20

[Forward] [Session 1] [Session 2] [Session 3] [Session 4]
[Session 5] [Session 6] [Session 7] [Session 8] [Session 9]
[Session 10] [Session 12] [Session 13] [Session 14] [Session 15]
[Session 16] [Session 17] [Session 18] [Session 19] [Session 20]

Forward **xxxv**

SESSION 1

Addressing Barriers to Watershed Management **1**
Robert W. Adler

Statewide Watershed Management: More Than Just a Promising Approach **5**
Trevor Clements, Clayton Creager, Kimberly Brewer

Approaching Messy Problems: Strategies for Environmental Analysis **9**
Leslie M. Reid, Robert R. Ziemer, Thomas E. Lisle

Clean Water Act Problems and Watershed Solutions **13**
Katherine A. O'Connor

SESSION 2

Water Quality Goals and Indicators--Draft February 15, 1996 17

Elizabeth Fellows, Mary Belefski, Sarah Lehmann, Andy Robertson

Monitoring Consortiums: A Key Tool In The Watershed Approach 21

Kimberly A. Brewer, Trevor Clements

Biological Monitoring Program Design to Address Questions at Multiple Geographic Scales: A Case Study 25

Sharon Meigs, James B. Stribling, Jeroen Gerritsen

Developing an Applied System of Ecological Indicators for Measuring Restoration Progress in an Urban Watershed 28

Andrew Warner

SESSION 3

Citizen-Directed Watershed Management: The Oregon Experience 32

Robert L. Horton, David J. Duncan, Marc Prevost

Water Quality 2000--Watershed Program Criteria 35

Carolyn Hardy Olsen, Margot W. Garcia

Lake Roosevelt: Successes and Failures in Building Partnerships 39

Ed Adams, Kelsey Gray

SESSION 4

Implementing Environmental Justice in Water Quality Programs 41

Deborah Alex-Saunders

Private Property Rights...Principles, Perceptions, and Proposals 44

LaJuana S. Wilcher, D. Randall Benn

Economic Considerations of the Restoration of a Tidal Salt Marsh: The Case of the West River 47

Lynne Lewis Bennet, Matthew Kirk Udziela

Planning Ahead with Regional Storm Water Management Facilities in Florida 51

Walid M. Hatoum, Moris Cabezas

SESSION 5

When The Dam Came Down- The Cold Creek Restoration Project 55

Joseph W. Thompson

Erosion and Sediment Control: Preventing Additional Disasters after the Southern California Fires 59

Carol L. Forrest, Michael V. Harding

Watershed Planning Study for Urban and Rural Pollution Sources 63

John Ricketts, Thomas R. "Buddy" Morgan, William Kreutzberger

SESSION 6

Summary of Proposed Stormwater Management Techniques for The Village of Woodsong as of January 31, 1996 66

Buddy Milliken

The Economics of Open Space 69

Elizabeth Brabec

SESSION 7

Moving the Watershed Planning Process from Quagmire to Success 70

B. Fritts Golden, John W. Rogers

Facilitating Natural Resource Dialogues on a Watershed Basis 73

Staci Pratt

Describing the Elephant: Multiple Perspectives in New York City's Watershed Protection Conflict 76

Krystyna A. Stave

SESSION 8

A Multiple-Watershed-Wide Modeling Approach of Dissolved Oxygen in New York Harbor 80

John P. St. John, Charles L. Dujardin, Warren Kurtz, Robert Gaffoglio

Watershed Nonpoint Assessment and Nutrient Loading Using the Geographic Information System-Based MANAGE Method 84

Lorraine Joubert, Dorothy Q. Kellogg, Arthur Gold

Indianapolis Uses New Radar Technology to Refine Hyetographs for CSO Model and SSES Studies **87**

Timothy George, Patrick L. Stevens

SESSION 9

Making the Most of State and Tribal Water Quality Assessment Data: New Tools and Approaches **89**

William Cooter, Julie Fountain, Peter Iliev, William Wheaton, Randall Dodd

Impacts of Upland Land Use on Runoff. "A Global Perspective." **93**

Gregory W. Eggers, Robert M. Bartels

An Assessment of Aquatic Resources in the Southern Appalachians **97**

Jim Harrison, Jack Holcomb, Lloyd W. Swift Jr., Patricia A. Flebbe, Gary Kappesser, Richard Burns, Jeanne Riley, Bill Melville, David Melgaard, Morris Flexner, John Greis, Cindy Williams, Dennis Yankee, Jim Wang, Neil Burns

SESSION 10

Water Quality and Farming Practices in an Agricultural Watershed **101**

J.L. Hatfield, D.B. Jaynes, M.R. Burkart, M.A. Smith

Watershed Scale Water Quality Impacts of Alternative Farming Systems **105**

Lynn King, Yan Zhou, Tony Prato

Watershed Modeling of Pollutant Contributions and Water Quality in the Le Sueur Basin of Southern Minnesota **109**

Anthony J. Donigian, Jr., Avinash S. Patwardhan, Ronald M. Jacobson

The Cross-Media Models of the Chesapeake Bay: Defining the Boundaries of the Problem **112**

Lewis C. Linker, Robert V. Thomann

Implementing a Rural Watershed Management Plan--Chewlah Creek **115**

Charles L. Kessler, Gordon Dugan

Model Alliance for Watershed Protection of How to Make a Cart Without Reinventing the Wheel **118**

Geoff Brosseau

SESSION 12

Integrated Resource Management--Achieving Multiple Benefits for the Same Dollar **121**

Timothy G. Rust, Ginger V. Strong, Allen S. Garcia

Diverse Partners with One Vision: The Bear Creek Watershed Restoration Plan **125**

Carol C. Chandler, L. Michelle Beasley

Using Formative Evaluation Strategies to Involve Landowners in Watershed Protection Planning **127**

Garrett J. O'Keefe

SESSION 13

One Size Does Not Fit All: Storm Water Is a Bigger Issue since Local Communities have No Regulatory Requirements through SCO Controls **130**

James Ridgway, Robert Tolpa, Ellen Lindquist, Roy Schrameck

The C&SF Project Comprehensive Review Study: Interagency Planning Team Integration **134**

Stuart J. Appelbaum

EPA Reaches Out to Local Governments **137**

Mindy Lemoine

University Contribution to Lake and Watershed Management: Case Studies From the Western United States-- Lake Tahoe and Pyramid Lake **140**

J.E. Reuter, C.R. Goldman, M.E. Lebo, A.D. Jassby, R.C. Richards, S.H. Hackley, D.A. hunter, P.A. King, M. Palmer, E. de Amezaga, B.C. Allen, G.J. Malyj, S. Fife, A.C. Heyvaert

SESSION 14

Market-based Approaches and Trading -- Conditions and Examples **145**

Waldon R. Kerns, Kurt Stephenson

Market Incentives: Effluent Trading in Watershed **148**

Mahesh K. Podar, Richard M. Kashmanian, Donald J. Brady, H. Dhol Herzi, Theresa Tuano

The Tar-Pamlico Experience: Innovative Approaches to Water Quality Management **151**

John C. Hall, Ciannat M. Howet

Cost-Effectiveness and Targeting of Agricultural BMPs for the Tar-Pamlico Nutrient Trading Program 154

Michael McCarthy, Randall Dodd, John P. Tippett, David Harding

SESSION 15

Nonstructural Management Practices for Watershed Protection 157

Rod Frederick, Robert Goo

A Watershed Approach to Flood Hazard Mitigation and Resource Protection: The President's Floodplain Management Action Plan 160

John H. McShane

An Approach for Planning and Managing Monitoring Activities for Major Flood Events 164

Mary L. Belefski, Joanne Kurklin, Richard Urban, Jim Yahnke, Jim Cook

Managing Watersheds to Reduce Flood Losses 167

Scott Faber

SESSION 16

Kagman Watershed, Saipan, CNMI 169

Dudley Kubo

Agricultural and Environmental Sustainability: A Watershed Study of Virginia's Eastern Shore 172

R. Warren Flint, Susan B. Sterrett, William G. Reay, George F. Oertel, William M. Dunstan

Farm*A*Syst and Home*A*Syst: Tools for Addressing Watershed Pollution Prevention Needs 176

Gary W. Jackson, Richard Castelnuovo, Doug Knox, Liz Nevers

SESSION 17

The Impact of Uncertainty on Risk Assessment with the AGNPS Model 180

Shane Parson, James Hamlett, Michael Foster, Paul Robillard

Modification of the WERF Methodology for Aquatic Ecological Risk Assessment for Assessing Watershed-Scale Aquatic Risks 183

Benjamin R. Parkhurst, William Warren-Hicks, Clayton Creager

Application of Aquatic Ecological Risk Methodology to Support Site-Specific Water Quality-Based Permitting **187**

Cynthia Paulson, Ben Parkhurst

The Use of Risk Analysis in Watershed Planning Activities **190**

David F. Mitchell, Don Galya, Betsy Ruffle, John A. Bleiler

SESSION 18

Developing Cost Effective Geographic Targets for Nitrogen Reductions in the Long Island Sound Watershed **194**

Mark A. Tedesco, Paul E. Stacey

Models of Nonpoint Source Water Quality for Watershed Assessment and Management **197**

Anthony S. Donigian, Jr., Wayne C. Huber, Thomas O. Barnwell, Jr.

A Compilation of Digital Geospatial Data Sets for the Mississippi River Basin **201**

Alan Rea, Joel R. Cederstrand

SESSION 19

A Time-Scale Perspective Applied to Toxicity Assessments Performed in Watershed Management Programs and Performance Assessments **203**

Edwin E. Herricks, Robert Brent, Laurence Burle, Ian Johnson, Ian Milne

Landscape Characterization For Watershed Management **206**

Carolyn T. Hunsaker, Paul M. Schwartz, Barbara L. Jackson

Watershed Analysis and Management: The Importance of Geology **209**

Craig Goodwin

Development and Application of Watershed Analysis to Washington State's Forest Lands **213**

David Roberts

SESSION 20

Structural Best Management Practices for Storm Water Pollution Control at Industrial Facilities **216**

John Botts, Lisa Allard, James Wheeler

Petroleum Hydrocarbon Concentrations Observed in Runoff From Discrete, Urbanized Automotive-Intensive Land Uses **220**

David L. Shepp

Environmentally Sensitive Low-Impact Development **224**

Larry S. Coffman, Jennifer Smith, Mohammed Lahlou

Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

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Addressing Barriers to Watershed Management

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Introduction

Historically, proposals for comprehensive water resource programs have shared a common theme: holistic analysis of whole watersheds or river basins. But they shared a common fate as well. They were ignored, adopted in name but not reality, or not implemented. Renewed proposals for watershed programs come from diverse sources. All propose to restore and protect aquatic resources on a holistic basis, taking into account all causes of impairment to, and the connected land and water resources of, target watersheds. Moreover, the quiescence of national watershed programs has not deterred the development of watershed programs at local, state and regional levels.

Definitions of "watershed management" or "watershed protection" vary, reflecting differing governmental and interest groups perspectives. Even the desired outcome of watershed programs varies significantly. As a result, some question whether the term "watershed protection" is too vague or rhetorical to be of significant use. Yet the watershed revival is too broad-based, and its underlying rationales too compelling, to dismiss so readily. The question is whether the watershed movement of the 1990s can produce adequate results to ensure its longevity. This paper seeks to identify, and to propose ways to overcome, the core barriers to watershed protection programs.

Imperatives for Watershed-Based Restoration and Protection

Ecological Imperatives for Watershed Programs

The need for watershed-based remedies is suggested by a synthesis of three ecological factors: (1) the

nature of aquatic ecosystems, including interactions between land and water, water quantity and quality, groundwater and surface water; and the heterogeneity (variability) of aquatic ecosystems; (2) the ongoing decline of aquatic species and ecosystems despite the implementation of point source pollution control programs and other "engineered" solutions; and (3) the nature of the major remaining sources of impairment, including habitat loss and alteration, polluted runoff, and declining instream flows, none of which are addressed well by existing source-specific programs.

Institutional Imperatives for Watershed Programs

It is difficult to imagine a political system as complicated and as fragmented as that used for protecting and managing water resources in the United States. Several institutional imperatives support the need for watershed-based approaches: (1) political fragmentation--the overlapping and conflicting division of responsibilities among multiple levels of government; (2) issue fragmentation--the artificial division of related water issues into separate programs (water quality and quantity, land and water use, surface and ground water); and (3) gaps in program design and implementation.

Economic Imperatives for Watershed Programs

While water resource protection deserves increased funding, political realities suggest that more must be done with less. Point source programs are challenged on grounds that they impose "treatment for treatment's sake," and that point sources have borne most of the water pollution control burden, while other significant causes of impairment escape with few if any requirements. This suggests two economic imperatives for watershed programs: (1) equity between sources of harm; and (2) efficiency in the use of scarce public and private resources.

Sociological Imperatives for Watershed Programs (Bioregionalism)

People are more willing to take actions and to make sacrifices to protect and restore a special place--like the Chesapeake Bay or the Great Salt Lake--than to promote the abstract idea of environmental quality. "Place-based" water resource programs can be explained by the concept of bioregionalism, increased allegiance to place. Bioregionalism can be harnessed to overcome the parochial tendency to resist regional cooperation, to bolster public support for funding and strengthened water resource protection and restoration programs, and to enlist volunteers for watershed restoration. Perhaps most important, bioregionalism could help to transform Aldo Leopold's theoretical but unrealized conservation ethic into changes in the behavior of individuals within their own watersheds.

U.S. Watershed Legislation Past and Present

Watershed management has a long history in the United States. Integrated watershed management was proposed by the 1908 Inland Waterways Commission, the 1909 National Conservation Commission, the 1912 National Waterways Commission, and the authorized but never formed 1917 Newlands Commission. Unfortunately, these proposals were subverted to promote massive federal spending on

structural water projects to optimize and "manage" the use and value of water for human benefits, in laws such as the Reclamation Act of 1902, the Federal Power Act of 1920, and the Flood Control Act of 1936. Broader New Deal-era proposals were rejected by Congress, largely due to opposition to central planning. River basin planning finally attracted Congress' attention with the Water Resources Planning Act of 1965 (WRPA). The WRPA was never formally repealed, but failed to accomplish its mission of basin planning on a national scale. Instead, all of the basin commissions were disbanded by President Reagan in 1981. Nevertheless, much federal statutory authority for watershed-based restoration and protection remains. Existing federal authority includes the Clean Water Act, other environmental protection statutes, federal land management statutes, and a large number of regional watershed protection or management programs. But while individual success stories abound, and other new programs show some promise, given empirical data on the state of our aquatic ecosystems it is hard to argue that these programs are succeeding on an overall basis. The design and implementation of future watershed programs must be improved if we are to meet aquatic ecosystem restoration goals.

Paradoxes in Watershed Program Design and Implementation

Scale

Hydrologic and ecological interactions over large geographic areas suggests that watershed programs should proceed at the scale of whole river basins or other large hydrologic regions. Watershed programs of broad regional scale, however, face significant political and institutional problems. Large watersheds cross many political boundaries, complicating intergovernmental coordination. Large watersheds also face technical challenges such as inconsistent water quality standards. At a smaller watershed scale, cost-effective goals, methods and solutions can be designed and implemented by those closest to the problem, taking into account the conditions of the particular area. But small watershed programs by definition lack the scope necessary to address hydrological and ecological linkages over space and time. Small programs might solve local problems while ignoring, or in some cases exacerbating, conditions in other areas, resulting in geographic externalities. Dividing watersheds into smaller units could subject water body protection to the very political pressures and competition that led to the enactment of a national clean water program.

The solution to the paradox of scale is "all of the above." Watershed programs should be planned and implemented at multiple, nested scales. Large (basinwide) watershed units should be used to establish and monitor broad regional goals and objectives. Small watershed units should focus more on design and implementation. However, nested scales of watershed organization must operate in cooperation rather than in competition. To avoid the "top down" versus "bottom up" paradox, information and decisions should flow in both directions. The goals of accountability, equity and consistency are served if overall goals are determined at the regional or national level, with participation by those who must implement the goals. Flexibility, cost-effectiveness and practicality may best be accomplished locally, but participation by regional officials can avoid inconsistent implementation or the sacrifice of regional goals to local economic interests.

Boundary

No agreement has been reached on a framework for environmental boundaries. Some advocate programs based on watershed boundaries, and others based on watershed ecosystems, but many different aquatic ecosystem boundaries could be identified--"salmonsheds" versus "ducksheds," for example. When terrestrial ecosystems are added, the situation becomes even more complex. Should programs be based on aquatic ecosystems (watersheds, ducksheds or salmonsheds), plant ecosystems (forestsheds) or on key terrestrial species (bearsheds)? There is probably no "correct" answer to this paradox; no single ecosystem delineation is more "correct" than others. However, unless agreement is reached on some consistent framework for watershed and other ecosystem programs, management anarchy may result.

Control

Watershed approaches can be used to coordinate the efforts of multiple levels of government as they affect an ecologically-defined region. Watershed approaches also provide flexibility to account for regional variables, so long as legitimate regional and national goals are met. Historically, however, opposition to regional watershed programs comes from lower levels of government who fear that they might sacrifice control over water use, land use, economic and environmental policies. Moreover, hydrologic units lack independent political power. Thus, a paradox exists between state and local rule versus the need to coordinate efforts within watershed or ecological boundaries. This tension may be exacerbated by watershed programs controlled too tightly out of Washington, D.C. History provides equally clear lessons, however, that leaving water policy decisions entirely to states and localities results in geographic externalities, economic inequities, and programs often too weak to make a real difference.

A reasonable compromise should incorporate the following principles: First, activities amenable to uniform controls, and for which variations produce economic and environmental externalities, should remain subject to national source controls. Second, overall goals should continue to be established at a national level, to avoid competition for economic growth at the expense of the environment. Variations that account for legitimate differences in environmental variables are appropriate, but equity is undermined if standards are allowed to differ in degree of protection. Moreover, for ecosystems that cross political borders, consistent if not uniform environmental goals and standards are essential. Third, especially for land use, runoff pollution and other sources of impairment that vary regionally, states and localities should retain some flexibility. However, this approach is viable and fair only if such standards provide comparable levels of control, using objective performance criteria, and achieve equivalent levels of compliance.

Mission

To some, the purpose of watershed programs is simply to ensure that the correct players from diverse locations and interests interact, express their views, and reach consensus on watershed goals and actions to meet those goals. This reflects an overly optimistic view that process alone will be sufficient to resolve intractable conflicts within and among watersheds. Where federal watershed programs have included

substantive mandates, however, in many cases they have done more harm than good to watershed health. Watershed "planning and management," a euphemism for water resource use and development, must give way to watershed restoration and protection. To achieve this change, watershed programs should be driven by clear, enforceable substantive mandates to restore and protect aquatic ecosystems. Moreover, federal and state laws and programs that do more to degrade than to protect aquatic ecosystem integrity should be modified or repealed in concert with restoration efforts. Otherwise, efforts to stabilize the patient will fail because the sources of illness will remain. Finally, the mission of watershed programs must be defined broadly. Some proposals continue to focus on single issues or sets of issues, such as water quality. Watershed programs should be designed to address, in concert, all activities that affect the integrity of the aquatic ecosystem within a watershed. Programs must encompass all aspects of the hydrologic cycle, including links between land and water, water quality and quantity, and groundwater and surface water.

Consistency

Previous efforts to establish nationwide watershed management were rejected in part due to resistance to mandatory federal programs affecting land and water use. Moreover, the resurgence of watershed programs around the country in the absence of a national mandate suggests that people and institutions may oppose when required what they may be willing to do when asked. However flexible a national program is intended, some believe that it will become encased in rules that stifle innovation. A voluntary, ad hoc system of watershed programs, however, will result in wide disparities between watershed protection and restoration around the country. Areas with political clout and funding may benefit, while others remain polluted. Some standardization would avoid the very confusion, gaps and conflicts that watershed programs are designed to address.

This paradox may be resolved by distinguishing between the components of watershed management that profit from consistency, and those that benefit from flexibility. Watershed programs may bemost effective if based on a uniform general method to delineate program boundaries with nested scales. Programs should be established for all major watersheds around the country. However, there is no need to reinvent watershed programs that already exist, and regions should be free to determine the appropriate system of smaller nested watershed programs.

An Evolving Standard Model for Watershed Programs

A standard but flexible model for watershed protection is evolving out of diverse sources of experimentation around the country. Gleaned from successful ongoing programs, new proposals, lessons from past and existing federal statutes and programs, and other sources, successful watershed programs share the following common characteristics:

1. Comprehensive watershed-wide resource inventories and evaluations form the basis for program design. The status of the resource, its potential health, existing sources of impairment, and potential solutions are catalogued and evaluated before final decisions are made or resources are

committed.

2. Specific goals and objectives are established, wherever possible using numeric or other objective performance standards. The standards can change over time, but specificity is critical to ensure program accountability and appropriate revisions. Goals and objectives should be established in environmental rather than bureaucratic terms.
3. Solutions should be selected and resources allocated based on careful targeting. In a world with unlimited resources, all solutions would be implemented. In the real world, and one of increasingly scarce public means, this is not possible. As the highest priority projects are completed, others are implemented until goals are met.
4. Decisions are made collectively, but ultimate program goals and objectives remain paramount, and binding, enforceable commitments to implementation are essential. All affected interest groups should be involved, using consensus decision-making aided by alternative dispute resolution methods where needed. Accountability to national, regional and local goals requires that some process be available to resolve impasses, and to mandate decisions and implementation.
5. The process must be iterative rather than static. Watershed programs must be dynamic to account for changing environmental and artificial factors, including shifting goals and values and to modify programs as needed. This process requires ongoing evaluation of program implementation and results, so that programs and strategies can be modified or retained as needed.

Conclusion

Persistent and skilful efforts to implement watershed programs around the country slowly appear to be eroding prejudices against cooperative, comprehensive planning for watershed protection and restoration. Difficult legal, political, social and technical barriers remain to nationwide implementation of watershed protection, but with persistence, those barriers can be overcome.

NOTE: This article is summarized from Robert W. Adler, Addressing Barriers to Watershed Protection, 25 Environmental Law 973-1106 (1995). References are included in the full article.

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Statewide Watershed Management: More Than Just A Promising Approach

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Introduction

A representative from North Carolina reported on a promising new framework for watershed management at the Watershed '93 Conference held in Alexandria, VA. North Carolina's Division of Environmental Management switched to a statewide watershed management approach, dividing the state into seventeen major river basins for focusing and coordinating a significant portion of their daily water quality management efforts. For each basin, key management activities are scheduled over a 5-year cycle: strategic monitoring, assessment, prioritization, management strategy development, plan documentation, and implementation. Basins are combined into five groups, and activities are sequenced such that approximately 20 percent of the state's basins are involved in the same activity simultaneously. This rotation provides geographic focus while balancing agency program workloads over time.

At the time of Watershed '93, South Carolina had implemented a similar statewide watershed management approach, and the States of Washington and Delaware were developing their own statewide frameworks. Now, three years later, Nebraska, Massachusetts, Georgia, Minnesota, and Utah all have implemented statewide watershed management frameworks. Several other states are in various stages of framework development, including Texas, Idaho, Oregon, California, Arizona, Alaska, and Tennessee. Additionally, New Jersey, Montana, and Florida are currently investigating the approach, and several other states have expressed interest in it.

Statewide watershed management is more than a promising approach for these states. The question is, "Why are these states making the significant effort to convert their water management programs to this approach?" After all, there is no federal mandate to do so! What are the incentives? This paper draws on the authors' extensive experience with statewide framework development to examine why these frameworks are being developed and why other states are likely to follow suit.

Incentives for Statewide Frameworks

The Need for Integrated Solutions

Billions of dollars have been spent to develop and implement tools and programs for protecting surface and ground water. Yet, problems remain, particularly nonpoint source pollution and habitat degradation. Because environmental problems often cut across media (land, water, and air), program purviews, and political jurisdictions, individual agencies often lack the authority and means to address problems fully. We now understand that critical environmental issues are so intertwined that mitigation and protection require a comprehensive approach that incorporates ecological principles and collaboration among agencies. Statewide watershed frameworks fill this need through geographic focus and a cycle of integrated activities.

Utah used its newly implemented framework to develop integrated solutions with two neighboring states for managing the Bear River Basin. First, a watershed team was formed as an informal partnership between local citizens and the state's water quality agency to promote stakeholder outreach. The team's structure and mission were clarified and empowered by the emerging statewide framework. Also, agency representatives from Idaho and Wyoming became members of the watershed team, allowing for evaluation of the river as a complete integrated system. The watershed team is developing an integrated management strategy that features physical habitat restoration for river channel and riparian corridor, upland BMPs to reduce extreme hydrological events and reduce nutrient runoff, and point source management options to reduce nutrients.

Cost Effectiveness

A common motivation for statewide watershed management frameworks is increased cost effectiveness. In a climate of decreasing budgets and increasing demands, public and private entities are searching for ways to make the best use of limited funds. Statewide frameworks often contain several cost-effective features, including

- Targeting staff and funds to address highest priority concerns.
- Pooling expertise and funds to solve common concerns among partners.
- Consolidating planning and implementation efforts by geographic region (e.g., permit public notices and hearings, monitoring, and modeling studies).

Although other approaches often include one or more of these features, statewide watershed management frameworks readily support all of them. Watersheds provide a natural unit for organizing stakeholders: partnerships for monitoring and assessment make cost-effective sense because stakeholders share waterways and drainage basins; jointly assessing watershed conditions leads to identification of shared priorities; targeting and consolidating efforts often result from the partnerships forged during the early stages of the management cycle.

Although information on cost effectiveness of statewide watershed management efforts is largely anecdotal, some documented figures demonstrate substantial cost effectiveness. For instance, South Carolina estimates that framework implementation yielded an additional 40-50 percent in collected water quality data and analysis for the same capital investment (personal communication with D. Chesnut, SCDHEC, June 26, 1995). In another case, North Carolina's returns from added investment in point source nutrient loading controls were diminishing in the Tar-Pamlico Basin. A nutrient pollutant trading program was established that allows a group of municipal and industrial stakeholders to fund more cost-effective nonpoint source controls within the basin in lieu of additional point source treatment (Tippett and Dodd 1995).

The Need to Demonstrate Environmental Effectiveness

The public and private sectors are more frequently demanding proof that their efforts are improving the environment. Stakeholders are not satisfied simply by knowing that permits are issued on time and that regulatory compliance is routinely assessed. The link between regulatory requirements and relative risk to the environment from regulated activities is of vital interest. Statewide watershed management frameworks are often suited to comparative risk assessments because they bring stakeholders together to identify priorities and corresponding risk indicators; produce better risk assessment information through leveraged resources; and focus management strategy development to solve problems that pose the greatest risk.

The State of Delaware, for example, is using its statewide framework as the basis for reaching a performance partnership agreement with EPA (personal communication with J. Schnieder, Delaware DNREC, September 6, 1995). Incorporating environmental indicators, watershed assessment, and priority-driven program implementation within their statewide framework has given the state a mechanism for demonstrating that block grants can be used to target environmental priorities effectively.

The Need to Grow Beyond a Top-Down Approach

Many traditional water resource management programs use a top-down approach driven by federal or state mandates, and they prescribe regulatory actions to solve specific problems. Although this approach is often justified, many of today's problems require innovative solutions tailored to take advantage of diverse stakeholder capabilities. Prescriptive approaches often impede progress in this regard, particularly when voluntary actions are needed. Stakeholders are less likely to support a solution unless they have a voice in how their time and funds are spent. Participants are demanding flexibility.

Statewide watershed management frameworks designed to link local, state, and federal public and private efforts recognize the benefits of integrating efforts from the grass roots level to top government levels. Participants develop a greater understanding of their roles, and the roles of their partners, when management moves toward restoration or protection goals. Statewide frameworks provide a forum that encourages integrated, innovative solutions that make effective use of stakeholder capabilities and are tailored to work under prevailing circumstances (e.g., block grants, phased TMDLs, pollutant trading, and site-specific standards).

In Georgia, use of basin advisory committees, stakeholder forums, and basin technical planning teams throughout a cycle of management activities ensures that priorities and management solutions reflect stakeholder input and participation. Specific problems are identified for each basin, and management strategies are tailored to meet the specific needs of the area. Pooling technical expertise and information and drawing from a large toolbox of stakeholder capabilities for implementing tailored management strategies are mainstays for their approach.

A Framework for Managing Multiple Objectives

Because many environmental programs are set up under specific, narrowly defined mandates, program managers often make decisions without regard to considerations outside of their mandate. Such an approach is neither practical nor possible for many local government and private sector managers that must make decisions regarding a host of objectives that reach beyond environmental goals. For example, in addition to worrying about municipal wastewater services and water supply protection, a local city manager will also be concerned about maintaining sanitation services, addressing transportation issues, and increasing local tax bases. A statewide framework can be designed to provide a basis for identifying management solutions that address multiple management objectives, distinguishing between basin-level and watershed-scale goals. Frameworks bring together stakeholders with different objectives such that agreed-upon solutions must often go beyond individual concerns and must place environmental protection in the context of other objectives.

In Alaska, the statewide watershed framework development work group includes a broad range of stakeholders with diverse objectives:

- Native corporations and federal resource management agencies that own and manage significant portions of the watersheds.
- Industry and environmental interest groups.
- Burroughs and large municipalities.
- Several state agencies and programs.
- Citizens from existing community-based watershed restoration projects.

Alaska's mission statement is directed to multiple-objective resource protection and management, and its framework allows for negotiated solutions. Watershed teams will plan and implement through common

steps designed to meet needs of participating partners.

An Improved Basis for Decision-Making

Both environmental and economic stakeholders want to know that management decisions are based on sufficient, accurate information. Statewide frameworks help build a stronger base of information by placing monitoring and assessment at the forefront of the management cycle and providing a forum for sharing information. Additionally, by focusing on goals to be achieved over several management cycles, a statewide approach reduces the tendency to operate in a reactive, or crisis, mode. Successive updates of management strategies can build on efforts in preceding iterations, adding continuity that may have been lacking prior to implementation of a statewide framework. Also, by bringing stakeholders' capabilities and concerns into the process, environmental management staff will more often create cost-effective recommendations_and recommendations that decision makers will be willing to adopt.

Washington State's watershed framework is designed to improve the basis of decision-making for their regulatory and non-regulatory programs. Monitoring studies are sequenced for consistency with the statewide watershed cycle for all twenty-two water quality management areas. Watershed teams comprised of participating programs and agencies meet with stakeholders to identify all information needs for comprehensive assessment and to develop a strategic monitoring/information collection plan. Implementation of the information collection plan results in a common database for all participants that enables stakeholders to target their efforts to the sources that can be most effectively reduced. The database is updated and improved with each iteration of the cycle.

Lessons Learned Along the Way

Establishing statewide watershed management frameworks is not without challenge. Much can be learned by the experiences of states that have already pioneered such approaches.

Statewide Watershed Management Is Not a Panacea

We do not want to leave the mistaken impression that this approach will solve all the complex problems associated with water resource management. Participants should recognize from the beginning that not all activities, programs, and resources belong within a statewide framework. The idea is not to force all management activities into a rigid framework, rather to provide a support structure for communicating and coordinating activities where integration is possible and beneficial. Framework development can be considerably smoother when participants tailor the approach to meet agreed-upon needs.

A Common Vision Should Be Defined Early

Partners will be in a better position to build a framework if they first achieve a common vision of what will constitute the statewide approach. Early efforts should involve identifying complementary and

supporting objectives, corresponding components and activities, key roles, and benefits for programs and organizations participating in the approach. Allowing partners to define their own levels of commitment and involvement greatly enhances this envisioning process.

Effective Leadership Is Essential

Statewide watershed management is unusual because it is not a program, nor is it developed in response to federal mandates or other requirements. In the absence of program-based incentives and until the statewide coordinating framework is established, effective collaboration among participants during the development process will be difficult without clear leadership. Therefore, a leader with strong communication skills should be appointed to facilitate open discussion and networking, and encourage commitment among participants.

Establish a Resource Base for Framework Development

Many statewide frameworks to date have been adopted on the basis of no net change to overall agency and program budgets after implementation. Initial planning efforts, however, require staff time for workshops, administrative support, framework development, and other preparation tasks. Partners should identify program resources that will be made available from the outset to support framework development. Such an allocation is a clear signal to participants that the statewide framework development process is important and worthy of their best effort. In many cases, this means reallocating resources from other tasks to framework development.

Phased Implementation Allows Time for the Approach to Mature

Partners should account for a transition period when moving to a statewide framework. For many, the change from a program-centered approach to a resource-based approach will require time for buy-in and refinement of operations. Partners should collectively decide on the scope and magnitude of initial activities to coordinate under the framework, and individually determine and communicate what they are willing to perform to maintain the support structure. Be visionary, but not too ambitious. Willing partners should take practical, first steps together in build a watershed framework while keeping the larger framework potential in mind.

Other Lessons Learned

Ground rules for the framework development process improve partner interaction. Work plans for framework development provide focus and milestones for measuring progress toward implementation. Holding educational forums on statewide watershed management early in the process provides participants with the fundamental understanding necessary to participate effectively, and documentation describing the consensus approach to statewide watershed management is essential to stakeholder understanding and implementation.

More information on developing and implementing statewide management frameworks is available from the authors. Additionally, the U.S. Environmental Protection Agency offers training and facilitation services for statewide watershed management.

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Approaching Messy Problems: Strategies for Environmental Analysis

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Environmental problems are never neatly defined. Instead, each is a tangle of interacting processes whose manifestation and interpretation are warped by the vagaries of time, weather, expectation, and economics. Each problem involves livelihoods, values, and numerous specialized disciplines. Nevertheless, federal agencies in the Pacific Northwest have been given the task of evaluating environmental issues quickly over large areas (USDA and USDI 1994a, REO 1995). Similarly, the Washington State Forest Practices Board promotes watershed analysis as a way to develop long-term land-use plans for large watersheds (Washington Forest Practices Board 1993), and California now gives blanket approval of Timber Harvest Plans for large areas of private land once a sustained yield plan is approved. All of these procedures require large-scale analyses of the causes and effects of past and future environmental changes. Similar efforts in other areas have labels like "watershed plans" and "ecosystem management plans."

In each case, analysis requires the description of past and present environmental changes, evaluation of their causes, identification of the issues and resources that are potentially influenced by the changes, and prediction of how conditions might change in the future. The areas subject to evaluation usually range between several tens to thousands of square kilometers, and the time allotted for analysis is generally on the order of several months to a year. Results are used to guide land-use planning, design restoration work, and interpret future changes. Fulfilling such a task requires new ways of approaching problems.

In the past, each aspect of environmental change usually was examined independently. Most problems were first simplified to make them tractable and then were assigned to a single discipline. Detailed information was then gathered and integrated from the point of view of the discipline involved to yield a picture of the problem, its causes, and its solution. For example, if salmon were scarce in a Pacific Northwest watershed, fisheries biologists would improve habitat by building structures in channel reaches shown by stream inventories to have little woody debris. Whether woody debris was naturally lacking, whether those structures disrupted other river uses, whether they could withstand high winter flows, whether that aspect of the environment was important for sustaining fish populations, and whether the structures actually worked to produce more salmon were usually not addressed to any significant degree.

As a mandate grew for evaluating more complicated issues, different methods began to be used. Most depended on reducing the complexity of the problem to a readily tractable level, usually by simply refining existing strategies. Approaches to complex problems thus continued to follow largely mono-disciplinary, data-oriented strategies that could be abstracted into well-defined protocols, or "cookbooks." Environmental indices or surrogate measurements became popular for assessing everything from regulatory compliance (e.g. the "Total Maximum Daily Loads" used by the EPA) to the potential for cumulative watershed effects (e.g. the "Equivalent Roaded Acres" used by Forest Service Region 5). Inventory became an important tool in support of this strategy since a map of the distribution of index values provided all of the information necessary for planning. Serious efforts were made to identify the seven indices that would allow the "health" of a channel to be "measured" in the Pacific Northwestern United States (USDA and USDI 1994b), and a parallel effort to identify the indices needed to describe watershed health throughout the United States was also initiated. The sufficiency of an analysis was conveniently evaluated on the basis of whether the analysis procedure was followed, not on the basis of whether the results were valid and useful for a particular application. Although the index approach fulfilled institutional requirements for consistency and simplicity, its shortcomings were increasingly recognized: it was not valid for the types of problems it was being applied to.

Now the scale and complexity of the required analyses has grown yet again, and approaches that rest on measuring site-specific indices or on accumulating details until a general picture appears are no longer feasible: even channels cannot be inventoried over a 500-km2 watershed in a 2-month period. In addition, each watershed provides a different suite of conditions, problems, and expectations, so no single set of procedures can be used to evaluate every watershed. It thus becomes necessary to develop efficient strategies for figuring out what physical, biological, and socio-economic interactions are important in a large area, and for figuring out how best to evaluate those interactions in that particular area.

As regulatory and land-management agencies wrestled with the institutional requirements for broad-scale environmental analysis, other methods were being developed for ad-hoc applications on much smaller scales. In some cases, people needed to know what had caused a particular impact. In others, people needed to know what impacts a proposed activity might have. At this scale, evaluations could be tailored to the particular needs of the specific application. Thus there were no institutional requirements for consistency or simplicity, but instead, an over-riding requirement for validity of the results. Two

complementary strategies for evaluating environmental problems were developed: the "bottom-up" and the "top-down" approaches.

The bottom-up approach proceeds from the point of view of a damaged resource or issue of concern, which is usually located near the bottom of the watershed. First, the types of existing or potential damage to the resource are identified. Next, the mechanisms that could produce those impacts are described. Finally, the historical changes in watershed characteristics (i.e. soils, vegetation, etc.; usually at upslope or upstream locations) that might have influenced these mechanisms are identified. Each step requires information from an increasing number of disciplines. This approach has often been used in "forensic" environmental studies: an impact has occurred, and an investigation is carried out to identify its cause.

In contrast, the top-down approach identifies land-use changes that have occurred in the watershed (often primarily in the uplands) and compares them to the natural disturbance regime. Changes in land-surface characteristics are documented, and the likely effects of these changes on hydrological, biological, social, and geomorphological processes are inferred. Each of these changes, in turn, is then examined to identify those influencing the focal problem (e.g. declining fish stocks or water quality downstream). Because each chain of causality involves influences that cross disciplinary boundaries (e.g. a change in vegetation influences runoff volume, and thus the utilization of water resources), this approach is also inherently interdisciplinary. The top-down approach has often been applied to "prophylactic" environmental studies: a project is proposed, and an investigation is carried out to identify its potential impacts.

The top-down approach is particularly useful for assessing impacts that occur away from the site of the triggering land-use activity. Most activities directly affect only a few land-surface characteristics, such as vegetation, topography, or soils. Most off-site impacts arise downstream of the triggering activity, and they can only occur because of changes in the production, transport, and storage of watershed products such as water, sediment, organic material, and chemicals. Changes in the primary characteristics can be evaluated to determine their influence on the watershed products and thus on the impacts of concern.

The top-down and bottom-up approaches work well for specific problems, but they require expertise and professional judgment instead of fixed protocols because the problems encountered are different everywhere. Both provide a means for understanding what is important in an area, and this is the primary objective for the new generation of environmental analyses. For these new applications, however, work must be carried out at a very different scale. Instead of being able to focus on a particular activity or impact, analysts must now evaluate the full variety of impacts that have occurred or might occur from many different activities. If the top-down or bottom-up strategies are to be applied to these broader problems, the strategies must be modified to make them workable.

Blind adherence to either of these approaches, of course, produces a rapidly broadening tree of potential causes and effects. The art of the analysis thus lies in discovering, as efficiently as possible, which branches can be lopped off and ignored. This can be accomplished in part by combining the two approaches. The first steps of each approach are the easiest, so carrying out the two in parallel provides an efficient way to evaluate the causes of a particular problem in a particular area, and can also be used

to survey and prioritize the full range of issues and changes that may occur in an area (Table 1). The conceptual structure provided by the combined approach also gives a framework for gathering and interpreting reconnaissance-level information. This organization shows what types of information can most efficiently focus the analysis, and it allows easier ranking of the importance of the various branches.

Table 1. A procedure for evaluating environmental changes in a watershed.

Objectives are to answer the question:

What changes are important, where, and for how long?

What caused those changes?

What changes are likely in the future, and where?

What can be done to improve conditions?

How can the condition of the watershed be best monitored?

***Procedure:**

Before beginning: Identify the types and location of information available for the area

1A. Identify the issues of concern	**1B.** Describe the history of land-use
2A. Identify existing or potential impacts to resources or values of concern	**2B.** Identify effects of activities on driving variables (e.g. vegetation, chemistry, soils, etc.)
3A. Identify possible mechanisms for impacts	**3B** Determine effects of altered variables on possible on-site and off-site impact mechanisms

4. Use results of first steps to prioritize the significance of impacts and impact mechanisms

5. Subdivide watershed according to factors controlling the most important impact mechanisms

6. Identify information and precision level needed to evaluate significance of mechanisms in each subarea

7. Carry out field work and office analysis needed to obtain the necessary information

8. Evaluate the potential significance of missing information (qualitatively, or worst-case estimates, or inferences using information from similar areas)

9. Use results (*italicized*) in combination with a basic understanding of process to answer the questions:
What changes are importan, where, and for how long? 1A, 7, 2B, 3B
What caused them? 1B, 7
What changes are likely in the future, and where? 1A, 7, 2B, 3B
What can be done to improve conditions? *To reverse causes, identify the steps at which the chain of causality can be broken most efficiently; to remediate effects, identify the conditions that are trending toward recovery so that these trends can be accelerated.*
How can the state of the watershed be best monitored? *Identify the locations most sensitive to the important changes, the time-scales over which response is likely, and the precision needed to detect meaningful changes.*

*Bottom-up (steps 1A-3A) and top-down (steps 1B-3B) approaches are carried out simultaneously.

The method outlined in Table 1 for combining the bottom-up and top-down strategies has been applied to problems as diverse as prioritizing watershed restoration needs in northern Tanzania (Reid 1990) and identifying flood hazards on Kauai (Reid and Smith 1992). In each case, the approaches were carried out in parallel (steps 1A-3A and 1B-3B), allowing the studies to increasingly focus on the most important topics. Identification of those topics then allowed the field- and office-work to concentrate on the most critical unknowns at a level of precision no greater than that needed to address the objectives. Each study area was divided into subareas likely to respond uniformly to the types of changes of concern (step 5), and the types of information needed to understand the problems were identified (step 6). Field-work and office-work were then carried out to provide the necessary information in each subarea. This framework for problem solving encourages progressive focusing on the most significant aspects of the problem, and it provides a structure that allows the relevance of particular pieces of information to be evaluated.

Although there is much discussion and concern about what is an appropriate analysis scale, adoption of these approaches essentially makes scale irrelevant. Instead, information is used from whatever scales are most useful for understanding the fundamental principles for each aspect of the problem. Regional information on a species' range may be combined with site-specific habitat sampling to evaluate the relative importance of different habitat types within a particular watershed. The same application may also require information from scales as disparate as those of DNA analysis and global climatic modeling.

Also important to the application of these strategies is acknowledgment that some essential information will always be unknowable. As long as these information gaps are identified, they can be evaluated for their significance and then worked around. In practice, however, more effort often goes into completing GIS coverage than is directed toward unraveling the fundamental unknowns that actually affect the understanding of an area. For the present levels of inquiry, complete data coverage is not necessary, and variations in data standards are irrelevant as long as the standards are understood.

Despite their history of application, these understanding-based strategies are met with discomfort by federal and state agency personnel who are in a position to use them. In the agency context, the aspects

of these approaches that are new, and therefore uncomfortable, are: 1) that the particular methods used depend on the setting and so cannot be codified into a cookbook, 2) that analysis requires very little site-specific data, and 3) that the strategies require an overtly open-minded, interdisciplinary approach.

The perceived necessity for a cookbook stems in part from agency culture and in part from environmental regulations that judge compliance on the basis of procedure. In the past, both oversight and quality control rested on procedural consistency. Only when results are routinely given peer review for validity can quality assurance needs be met in the absence of a consistent procedural protocol. The reverence for data and the devaluation of qualitative understanding also stem from agency culture and regulations. Numbers are assumed to be capable of proving things, while qualitative information is perceived to be subject to interpretation.

Much of the apparent complexity of environmental problems arises from their interdisciplinary nature. No one person has the professional background required to understand fully the nuances of any one problem. A problem might thus be no more complicated inherently than one that falls completely within one discipline, but it will seem to be more complicated because of the arbitrary boundaries that western science has drawn around disciplines. In this sense, part of the difficulty of problem solving arises not from the problem itself but from the socio-cultural impediments to people from different disciplines working together, just as management of a river on the boundary between two nations is more complicated than management of a river located within a single country. These problems will become easier as representatives of different disciplines develop the skills needed to work with one another and as examples of successful interdisciplinary analyses are recognized.

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Clean Water Act Problems and Watershed Solutions

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The Clean Water Act established comprehensive national policies for water quality management. However, this policy was stated over 20 years ago, and some of the original water quality problems still exist today. Only now, there are a multitude of federal, state and local government agencies with responsibility for implementing water quality control programs. This paper outlines the shortcomings of the existing national approach to water quality management. It explores reasons for the apparent failure of the water quality programs, and presents nine major obstacles to the successful implementation of the policies of the Clean Water Act.

Restoration and maintenance of the integrity of the nation's waters is the overall objective of the Clean Water Act, but the current policy suffers from ineffective management of disparate issues involving environmental, social, economic, political, legal, and regulatory challenges to water quality management. The failure to meet the national goals for water quality can be attributed to the following reasons: (1) lack of coordination between agencies and their programs; (2) fragmented authority and responsibility; (3) lack of accountability; (4) fragmented approach to water quality problems; (5) conflicting goals and objectives of agency programs; (6) failure to address problems of individual watersheds; (7) overlapping boundaries and jurisdictional disputes; (8) strict regulatory mandates with little or no funding provided to local governments; and (9) societal impacts such as increasingly strict regulations which interfere with private property rights, and a lack of public participation in water quality planning process.

The diverse water quality issues confronting the nation include major types of pollution that remain unregulated or uncontrolled, the so called "unfinished business" of the water quality programs. Most of these water quality problems are diffuse pollutants from unregulated nonpoint source discharges, resulting from various activities that take place in a watershed such as agriculture, animal production, airborne pollutants, boating and marinas, development and urbanization, flood control activities, mining activities, urban runoff, wastewater treatment and on-site septic systems. The general constituents of the water quality pollutants include: eroded soils, sediments, toxics such as heavy metals and synthetic organic chemicals, conventional pollutants such as biochemical oxygen demand, oil and grease, nutrients, and pathogens which include bacteria and viruses. Nonpoint sources of pollution remain the "unfinished business" because they result from such a variety of human activities, and are not as easy to regulate with individual permits as with the point source discharges.

There are numerous federal, state, and local government agencies, with specific programs related to water quality management, but there is no comprehensive system to coordinate their actions. For the most part, these agencies implement the programs independently, without interagency cooperation. Bogged down in this mire of legislation, agencies are forced to muddle through a regulatory maze and are prevented from effectively using the tools available to them to meet their statutory requirements for water quality. This myriad of statutes and agencies forms a patchwork of conflicting goals and objectives. Many times government agencies work at cross-purposes to each other, which eventually results in intergovernmental conflict, and the canceling out of agency action, or actions which are inconsistent with water quality values.

Fragmented authority and responsibility for programs with different and sometimes conflicting goals, result in a piecemeal approach to water quality management. Because the responsibility and authority is divided, there is often no clear linkage to enable these agencies to work together, resulting in overlap and duplication of effort. In some situations, there is a lack of accountability for where the pollution came from, as is the case with nonpoint sources of pollution. When responsibility for pollution control is not clearly delineated, program implementation is often inconsistent, and there are gaps in enforcement. Disputes occur among agencies when their mandated

responsibilities overlap with those of another agency, or when the geographic boundaries of watersheds overlap with the political jurisdictions of another agency. Unfortunately for water quality management purposes, water pollution does not respect political boundaries.

Many programs fail to eliminate pollution because their approach fails to recognize the interrelated processes and important linkages in the ecological systems of watersheds. Short-term solutions to water quality problems are implemented based on the political jurisdictions of states and counties, instead of being based on ecological time frames and watershed boundaries. The programs also fail to comprehensively address the unique problems of individual watersheds and instead impose national "one-size-fits-all" regulations that are inappropriate or inadequate for the local conditions. Strict national mandates with lofty goals are imposed, placing the financial burden of implementation on the state and local governments. These policies also fail to consider their social impacts, or involve the affected stakeholders in the decision-making process. The nation's water quality is nearing a condition where a new approach is needed for effective water pollution control.

Watershed management planning is an alternative approach to water pollution control which addresses the major problems of the current system identified above. The approach addresses not only the administrative problems challenging the programs, but the existing water quality problems as well. Watershed management planning is an integrated and holistic approach to water pollution control that considers all possible impacts to water quality in a watershed and can successfully address water pollution that presently remains uncontrolled. The watershed approach more effectively implements the regulatory tools for water quality management to achieve the goals of the Clean Water Act.

The fundamental elements of watershed management planning include: (1) Definition of the watershed, or planning unit; (2) Assessment of water quality problems in the watershed; (3) Planning activities within the watershed basin, including ranking priority concerns; identifying stakeholders; and developing overall goals for the watershed; (4) Development of the watershed plan, including resource management strategies for the specific water quality goals and objectives; identification of the various stakeholders' roles and responsibilities; and establishment of a time frame for implementation of the programs; (5) Implementation of the watershed plan; and (6) Monitoring and evaluating the watershed plan's effectiveness. The watershed approach does not replace or compete with any ongoing programs for water pollution control; it improves their effectiveness, enabling the watersheds to meet the water quality objectives of the Clean Water Act.

Watershed management planning can be implemented by existing federal, state, and local agencies already authorized to implement water quality programs under the Clean Water Act. The Clean Water Act established the foundation of required actions for water quality management including agencies and programs for pollution control, national water quality standards, regulations, discharge permits, and effluent limits. Watershed management planning fits into the context of the Clean Water Act, without needing changes in the law, or the adoption of any new laws (EPA 1994, 1-8).

Watershed management focuses on redirecting the efforts of the myriad of agencies and programs with responsibilities for water resources and pollution control to meet the overall objective of the Clean Water Act. One of the intentions of watershed management is to integrate the many national programs for water quality and resource management that are currently operating independently. Watershed management planning can reshape the implementation of these individual programs of federal, state and regional agencies, to focus on comprehensive watershed management goals. This can be accomplished by the existing infrastructure established by the Clean Water Act (EPA 1993, 1-8).

The tools for water quality control are already in place in the watershed; the watershed management approach entails developing new policies to use the tools more effectively. One of the integral concepts of the watershed management approach is the recognition of the ecological complexities of the natural systems in the watershed, and the interconnectedness of these various components. These linkages may not always be readily apparent, but they must be accounted for in the watershed planning process. The watershed management planning process incorporates a holistic approach which acknowledges the linkage between all the elements of the watershed.

In addition, the watershed planning approach works within the political and economic realities of the watershed. The watershed planning approach incorporates risk-based strategies for water quality control programs, and decision making that coordinates the private sector, government agencies, and public interest groups as a team. The approach refrains from employing unfunded mandates, and instead promotes multi-agency cooperation in the planning process that includes those who will implement, enforce and pay for water quality control programs. The watershed planning approach protects private property rights and works to avoid "takings," thus promoting natural resource stewardship.

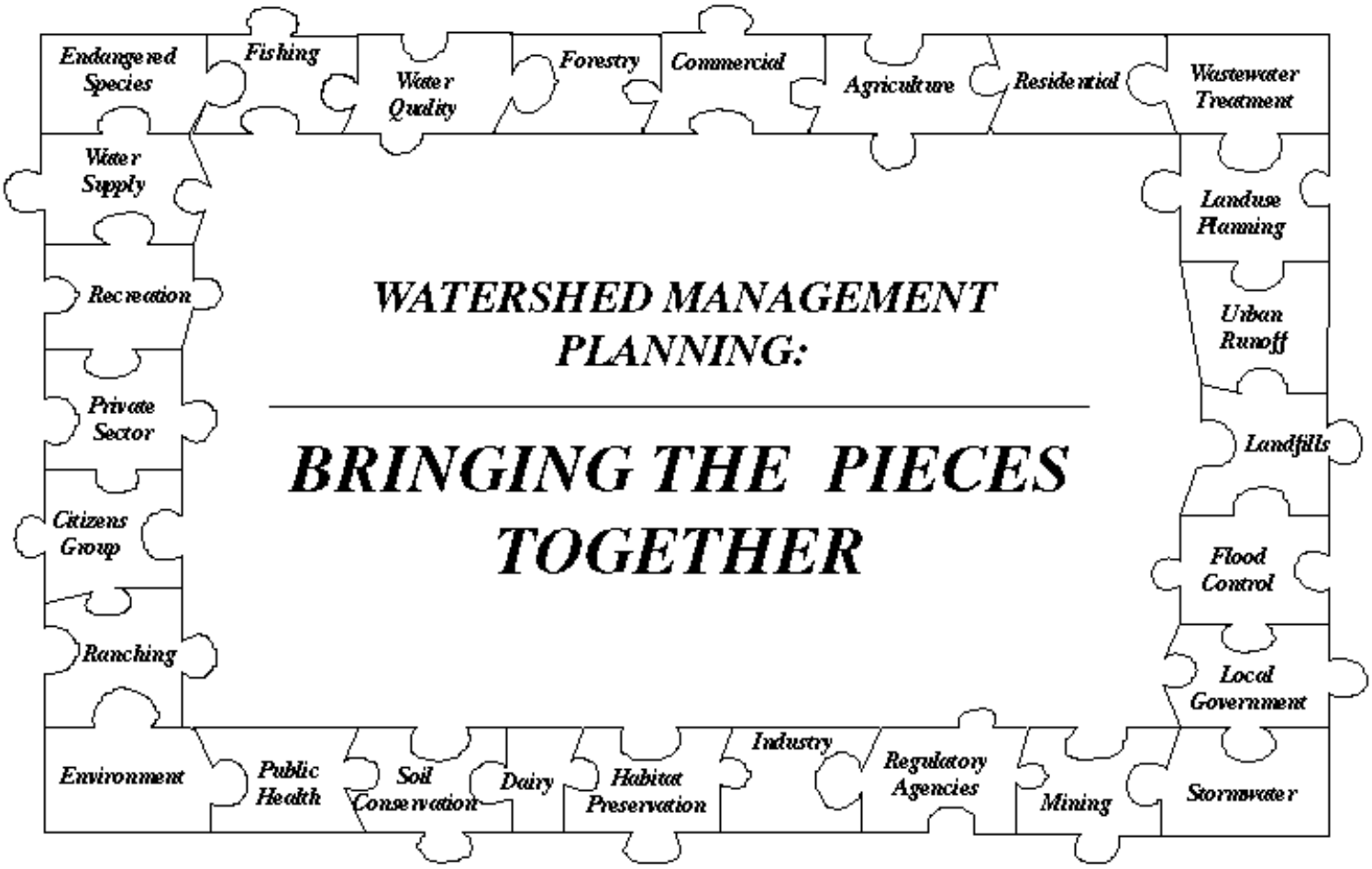
The watershed planning approach establishes management priorities based on the quality and uses of the waters, the health of the ecosystem, and the sources of water quality pollutants. The approach advocates use-attainability analyses to provide better scientific data and more relevant information to the decision makers and regulators. Furthermore, the watershed management approach supports the use of site-specific water quality standards which are based on the local conditions of each particular watershed. The local governments are empowered to make water quality decisions for the watershed, replacing federal command-and-control regulations with national leadership. This "bottoms-up" approach to water quality management in a watershed encourages partnerships among local interests, state, and federal government agencies. In addition, the general public has the opportunity to participate in the planning for the water quality programs in their community.

The watershed approach seeks to coordinate the efforts of the various agencies implementing water quality management programs in the watershed. This shared responsibility, combined with a holistic viewpoint, should prevent overlaps and promote consistency among the different programs within a watershed. The fragmented, piecemeal approach to water quality management can be averted through the watershed approach, which reconciles the differences between the numerous programs to avoid interagency conflicts. By establishing links between the differing goals of the management programs, the watershed approach should encourage cooperation between agencies, and turn conflicts into compromises.

The watershed management approach determines accountability for previously unregulated and uncontrolled pollutants. The approach employs nontraditional methods to reach timely and cost-effective solutions to water quality problems. Pollution is prevented or controlled at the source, instead of resorting to end-of-the-pipe treatment. In addition, watershed management assumes a multimedia approach, and addresses pollutants as they exist in all forms, not just in water.

There are many components of water resource management that make up a successful water quality management program. A watershed approach combines these components, which include: (1) wastewater treatment in a manner that causes the least environmental impact and prevents cross-media contamination throughout the watershed, (2) water reclamation to provide a continuous, non-interruptible supply of water, reducing the dependence on water imported from outside the watershed, (3) ground water recharge of water supplies, including the injection of reclaimed water into the ground water aquifers of the watershed, (4) source control and pretreatment of toxic pollutants by industries that discharge into the sewer systems of the watershed, (5) the control of nonpoint source pollutants and contaminated runoff from industrial, commercial, and residential sites, including nutrients and synthetic organic chemicals from forests, agriculture, and landscaping, (6) environmentally sensitive flood control management facilities which can divert and store storm water for later use, and the (7) maintenance and protection of wetlands and similar areas so that they retain their important functions such as coastal marine and inland freshwater wetland habitats for fish and wildlife, natural flood control basins, and filtering systems for pollutants.

Watershed management planning is not another layer of government. It is an approach that involves a new way of developing programs that can be successfully implemented at the watershed level. The water quality control programs are consistent with, and fully integrated into, the existing local, state and federal regulatory structure of the watershed. The approach is analogous to the frame of a puzzle, shown in Figure 1. Watershed management planning forms the framework that brings all the different pieces of the water quality puzzle together: the various levels of government, the assorted laws that regulate water quality, the individual agencies that enforce these laws, and the programs that they implement. All this takes place on the backdrop of the individual watershed, with its distinctive characteristics: climate, ecosystems, topography, soils, water types, habitats and wildlife, and the activities of the human habitats of this watershed.



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Water Quality Goals and Indicators_Draft February 15, 1996

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This paper details the importance of using goals and indicators to present water quality information and measure progress toward clearly identified goals, discusses the first National Water Indicators Report published by the Environmental Protection Agency's (EPA) Office of Water and its public and private partners, and provides criteria developed by the Intergovernmental Task Force on Monitoring Water Quality (ITFM) for designing indicators at the national, watershed, or local scale.

Why are Goals and Indicators Important?

All organizations direct their activities toward achieving specific goals and objectives. Indicators provide a means for organizations to measure progress toward achieving those goals and objectives, as well as to evaluate the effectiveness of programs and express information clearly. Indicators have been used for years in the economic arena_an example is the Gross National Product. The nation needs an equivalent set of environmental indicators.

Framework for Organizing Indicators

A common way of organizing different types of indicators, especially environmental indicators, is the Pressure/State/Response framework. In this framework, used nationally and internationally (WRI, 1995), indicators are categorized into three groups:

- Pressure_the human activities that impact environmental conditions.
- State_the actual condition of the environment.

- Response_the societal actions undertaken to improve and protect the environment.

All three types are necessary to completely understand changes occurring in the environment, causes for those changes, and the effectiveness of specific programs in encouraging positive trends.

Water Environmental Indicators

Using environmental indicators is an effective way for organizations operating within a watershed to measure achievement toward water quality goals. Indicators are also vital for presenting information to policy makers, program managers, and the public. The Intergovernmental Task Force on Monitoring Water Quality (ITFM), made up of representatives from federal agencies, states and tribes with advice from municipalities, academics, and industry, established a task group to specifically address the issue of water quality indicators. In a 1994 report, the ITFM defined an environmental indicator as a ". . . measurable feature which singly or in combination provide managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality." This means that an indicator must be suitable for: (1) measuring established goals with available technology, (2) determining the effectiveness of programs, and (3) presenting trends in quality in a simple, understandable fashion. By shedding light on changes in water quality and seeking to identify causal relationships, water quality management decisions can be made more easily.

Story of National Application

In the United States, a number of efforts are underway that make use of or promote the use of environmental indicators at various geographic scales. When indicators are carefully designed, site specific information pertinent to watersheds can be aggregated up and presented so that it is useful at broader scales as well. The following sections discuss efforts underway on goals and indicators.

EPA's National Goals Project

At the federal level, EPA has initiated an agency-wide project implementing goals and indicators, known as the National Goals Project. This project is responsible for setting long-range national environmental goals, selecting indicators to measure progress towards these goals, and specifying milestones that mark predicted improvements in environmental conditions by the year 2005. The information conveyed within the report will improve managers' ability to relate plans, budgets, and program evaluations to outcomes. The National Goals Report sets forth two goals for our waters:

- Safe Drinking Water Goal_Every public water system will consistently provide water that is safe to drink.

- Clean Water Goal_All waters will be safe for people to use and will support healthy communities of fish, plants, and other aquatic life. Surface waters will be safe for fishing and swimming, and providing drinking water sources. Ground waters will be safe for intended uses. Remaining wetlands will be protected, and many that have been lost will be restored, helping to support fisheries and to prevent devastating floods and drought.

Office of Water Indicators

The EPA's Office of Water (OW) spearheaded a national process to define indicators of water quality. OW and its partners have agreed on five objectives for meeting the two goals listed above:

- Conserve and Enhance Public Health.
- Conserve and Enhance Ecosystems.
- Support Uses Designated by States and Tribes.
- Conserve and Improve Ambient Conditions.
- Reduce or Prevent Pollutant Loadings.

Indicators designed to measure progress toward meeting the overall objectives were selected in a series of public meetings attended by representatives from EPA, other federal agencies, states, tribes, community groups and private organizations. A number of these indicators are also incorporated in the National Goals Report. These objectives and indicators will assist EPA and its partners to communicate vital national water quality information to policy makers, water quality managers and the American public.

Figure 1 depicts the relationship between water objectives and the indicators selected to measure progress toward those objectives and goals.

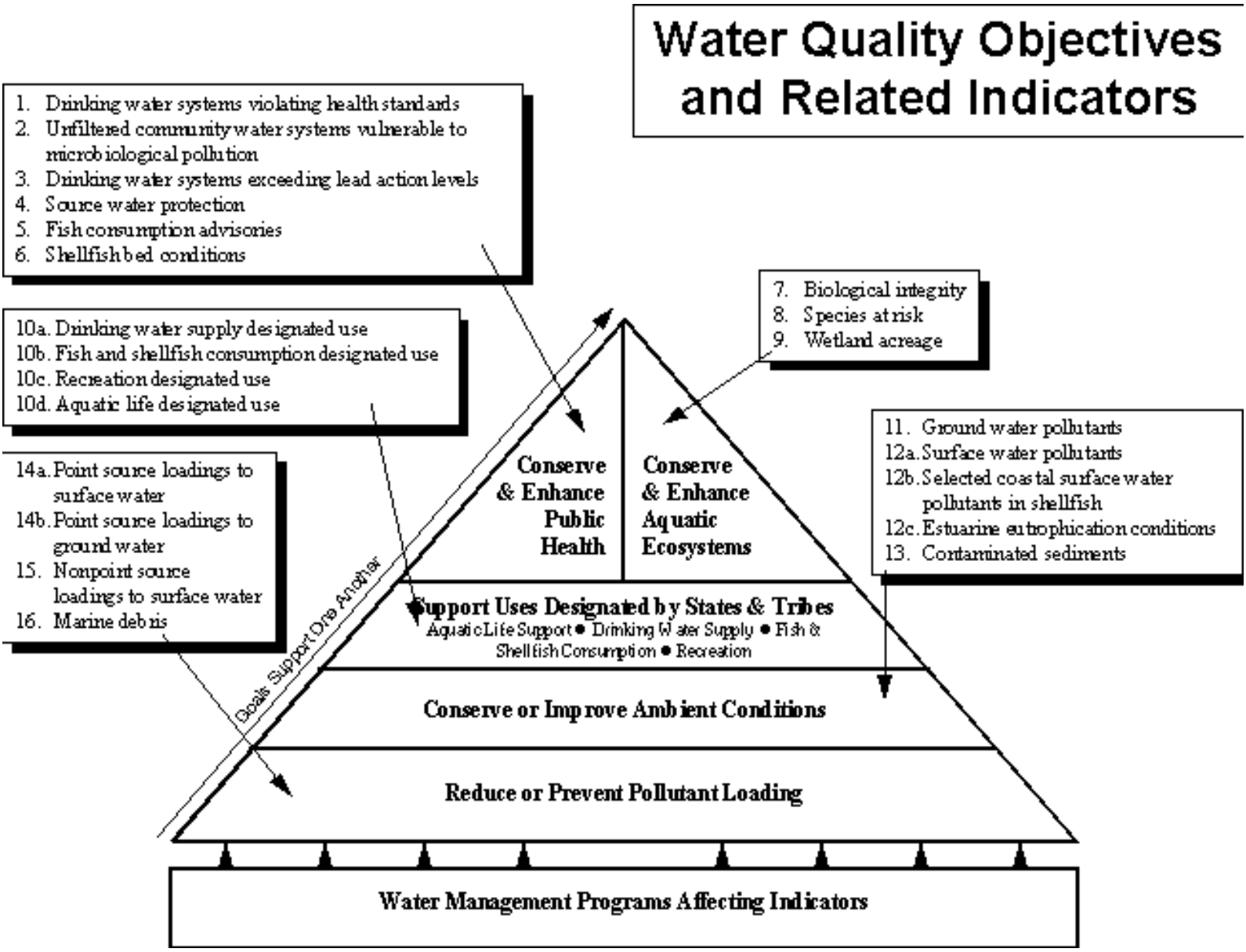

Figure 1. Relationship between water objectives and the indicators selected to measure progress toward those objectives and goals.

Development and Application of Indicators Within the Watershed

Indicators are not only useful at the national level. Developing and using indicators is important for communicating information about water quality at all geographic and political scales. The Intergovernmental Task Force on Monitoring Water Quality (ITFM) developed a system for selecting indicators with applicability at a variety of scales. In particular, ITFM emphasized the need to establish both a spatial framework for organizing data and indicator selection criteria. The ITFM in a workshop recommended that these indicators also be considered at state and watershed scales.

Watershed and Ecoregion Frameworks

One important method for improving environmental information is determining a logical spatial framework within the watershed to collect information. For example, this method was recommended by ITFM for the development of a biological integrity indicator. The ITFM notes that selecting a framework to organize

environmental information based on geographic patterns can assist in accomplishing the:

- Establishment of common monitoring goals and objectives.
- Development of indicators that are meaningful on a site specific basis and have broader scale significance.
- Cooperative development of monitoring methods.
- Interstate usage of reference sites.
- Use of common reporting goals.

The ITFM recommends using a combination of the ecoregion and watershed concepts as one national spatial framework for organizing environmental information. The ecoregion framework (Omernik 1987, 1995) was developed and is being refined using multiple environmental characteristics such as climate, vegetation type, hydrologic drainage areas, etc. It has several advantages for improving the data collected throughout the country including that it provides an ecologically relevant system for classifying landscapes and drainage areas for monitoring; is independent of political boundaries which allows for shared resources, data and criteria (translates into potential cost efficiencies); and provides a logical classification of sites for the establishment of reference conditions. By using the ecoregion concept, it is possible to categorize information by region, or further refine the information into subregions and watersheds.

Selection Criteria

To help groups select indicators that will provide useful information, the ITFM developed selection criteria. The indicators must be scientifically valid, meet practical considerations such as cost effectiveness, and take into consideration specific programmatic needs. Figure 2 provides ITFM's detailed guidelines for selecting indicators.

Indicator Selection Criteria	
Scientifically Valid: Measurable/quantifiable; Sensitive to a broad range of conditions-- and geographic scales; Valid and accurate; Reproducible; Resolution/discriminatory power; Integrate effects/exposure; Representative; Scope/applicability; Reference value; Data comparability; and Anticipatory	**Practical Considerations:** Cost/Cost effectiveness; Level of difficulty; and Minimal environmental impact **Program Consideration:** Relevance; Program Coverage; and Understandability for the target audience

Figure 2. Indicator Selection Criteria

Conclusion

Goals and indicators provide watershed professionals with the framework for measuring the outcomes of their programs. Strong monitoring and data management programs are also needed to provide the valid information to measure indicators. Data will come from a variety of agencies and organizations. Strong monitoring and data sharing partnerships are essential to support indicators, which must include: (1) strong monitoring programs, (2) improved national data systems to store, retrieve, and share data, (3) good analysis techniques, and (4) better reporting of information.

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Monitoring Consortiums: A Key Tool In The Watershed Approach

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Introduction

Many environmental resource managers are turning to a watershed approach to restore and protect natural resources. Key to this watershed approach is management that integrates a wide range of technical expertise, regulatory and non-regulatory authorities, and strategic implementation. Increasingly, limited program resources intensify the need for strategic, coordinated management and for decision making focused on priority environmental concerns. Well-defined priorities depend on solid assessment of good information; good information depends on well-designed monitoring programs. In recent years, numerous monitoring partnerships, or consortiums, have been formed as flexible tools: their purposes may vary from water supply protection, to coordinated, whole basin wastewater discharge management, to ecosystem assessment. Key to each consortium is pooling funds, expertise, and capital to monitor a watershed or ecosystem. In the following three, varied case studies, this report highlights how partnerships have been formed; who participates; cost_and cost savings_of the monitoring program; benefits to participants; obstacles overcome; and helpful advice about building and maintaining strong consortiums.

Case Studies

The San Francisco Estuary Regional Monitoring Program

How Was The Consortium Formed and Who Participates? The San Francisco Regional Water Quality

Control Board (the Board), whose Basin Plan and NPDES permits govern water quality and discharge of chemical pollutants to the San Francisco Estuary, initiated the Regional Monitoring Program (RMP). To implement this Program, the Board required strategic monitoring of permittees in the region, encouraged a cooperative approach, provided flexibility in permitting, and involved the whole group early in the program design and decision-making process. During the early discussions, the region's Bay Area Dischargers Authority identified concrete potential benefits for each permit group. The first formal step in forming the consortium was creating a strategic monitoring plan that specified the responsibilities of the participants and the standard operating procedures.

The Board has responsibility for the regulatory structure that drives the RMP, for selecting permittees that must participate in the program and notifying them of their responsibility, and for organizing the program's financial structure. Sixty-two local financial sponsors, or permittees, are members of the consortium. Permittees participating in the consortium pay for the monitoring and analysis, based on the proportion of pollutants discharged into the Bay. Those who do not participate in the consortium are required individually to conduct strategic monitoring and reporting. In addition to these partners, two federal partners operate through cooperative agreements: the US Geologic Survey and the US Army Corps of Engineers. Finally, many federal, state, and local agencies coordinate monitoring with the Regional Monitoring Program. Through a Memorandum of Understanding with the Board, the San Francisco Estuarine Institute is responsible for implementing the monitoring program and for cost-effective expenditure of its funds.

Program Cost and Cost Savings. When first implemented in 1993, the program budget was $1.15 million. Since that time, the Program's current annual budget has approximately doubled to $2 million. Initially, QA and data interpretation were the most underestimated program costs. Finding ways to meet the growing budget demands while holding down monitoring costs for local participants has become a significant challenge for the program. The program currently has a local resource leveraging factor of 1.17 (i.e., the program budget divided by the local permittee contributions). The program budget includes the federal cost match but excludes the university research funds. Hence the leveraging factor is a conservative estimate. The prorated annual contribution charged to the smaller permittees is less than their previous individual monitoring costs.

Program Benefits. The consortium identified four key benefits to cooperative monitoring: higher quality, more useful data; better assessment and understanding of the estuary; cost-effectiveness; and cooperative decision-making.

Program Challenges.

- Ensuring the monitoring program helps to meet regulatory objectives.
- Distributing program cost equitably.
- Effectively communicating the value and findings of the project to decision-makers.

- Using the program findings in making decisions (such as permit requirements).
- Staying cost-effective.
- Making sure the data collection and interpretation is technically sound.

The Triangle Area Water Supply Monitoring Project

How Was The Consortium Formed and Who Participates? The Triangle J Council of Governments' 1987 World Class Region Conference, with about 500 local elected officials, business leaders, environmentalists, and other citizens in the region attending, called for the Triangle Area Water Supply Monitoring Project. Providing a neutral forum, Triangle J formed a task force comprising city managers and public utility directors and drawing resources from universities, the North Carolina Division of Environmental Management, and the US Geological Survey. The Task Force designed the project, drafted by-laws for project governance, and negotiated a draft interlocal agreement.

Eleven city and county governments entered into a three-year, Phase I monitoring agreement with the understanding that 1) the project's objectives would require many additional years of monitoring, and that 2) three- to four-year phases were appropriate for major data interpretation studies and for program evaluation. The participating local governments appointed staff representatives to the project steering committee that makes technical, financial, and administrative recommendations to the participating local entities. Non-voting resource advisors from NCDEM, US Geological Survey, and local universities also participate on the steering committee. The Steering Committee has a cooperative agreement with USGS for sampling, lab analysis, and data interpretation and a contract with Triangle J COG for overall project management.

Program Cost and Cost Savings. The Monitoring Project's proposed Phase III annual budget is $443,0000. Local governments and the USGS each pay one-half of the monitoring costs. Adding the value of the NCDEM data contributions, the project's estimated cost/value is $543,000. Since the total cost for the local participants is only $231,733, the project has a local leveraging factor of 2.34. The project has held constant or decreased the program's cost to local governments. However, since this is a supplementary monitoring program in a period of increased federal monitoring requirements, several members decided not to participate in Phase III of the project.

Program Benefits. Because multiple local governments, the State, and the USGS share interests in individual sites, the regional monitoring program cost is much lower than multiple programs. For example, the Orange Water and Sewer Authority has a direct interest in nine of the thirty water quality monitoring stations and four of the thirteen gaging sites. The monitoring, analysis, and management cost of these sites is approximately $164,000/year, while the Authority is only assessed $23,000_a leveraging factor of 7. The resource leveraging factor per jurisdiction varies depending on the size of the jurisdiction as well as on the number of sites of direct interest. Also, the project allows participants to collect,

analyze, and interpret data that they would not be able to do on their own, e.g., the spatial and temporal trend analyses and pollutant loading studies. The data have been used in specialized watershed protection studies across the region. By providing flexibility in the project's annual budget, the monitoring program is responding to emerging issues such as cryptosporidium.

Program Challenges.

- Coordinating with the monitoring conducted by the state, using a performance-based monitoring approach, poses logistical and procedural challenges.
- The Project asked the state to allow its local governments to use the raw water sampling data from the intake area in lieu of the same treated drinking water requirements; this request was denied.
- Additional Safe Drinking Water Act Requirements reduce local funds available for supplementary monitoring and participation in the program.
- The local share formulae that reflect each participant's % of water production, although devised by participating local governments, at times is a challenge for program governance, since it does not reflect the % of benefits derived from the program (i.e., number of sites of interest being monitored).

The Lower Neuse Association

How Was The Consortium Formed and Who Participates? In 1992, the state DEM targeted the Neuse Basin as its first basin-wide water quality management study area. During the basin planning and assessment stages, DEM reviewed the NPDES permittees' data and the state's ambient monitoring data and concluded that through a more flexible, basin-oriented monitoring design, all parties could generate more useful, cost-effective, higher-quality data. DEM initiated talks with some of the larger wastewater dischargers in the region about a coordinated, strategic monitoring program that would replace the routine NPDES compliance monitoring. The largest discharger, the City of Raleigh, assumed the lead role in recruiting and organizing others. The state DEM designed the Association's monitoring Program.

Twenty-three municipal and industrial dischargers constitute the Association that signed a Memorandum of Understanding with the state DEM to implement the strategic monitoring program. The Association, managed by the City of Raleigh, contracts with a private lab for the field sampling and lab analysis.

Program Cost and Cost Savings. The Association's annual budget is $132,000. To allocate cost, each member is charged a % of the project's annual budget based on its % of the Association's total permitted flow. Comparing the former compliance monitoring costs to the Association's monitoring cost shows an annual net savings for local participants of $165,000 and an overall monitoring cost-savings factor of 2.0 (estimated preassociation monitoring cost of $297,000 compared to association monitoring cost of $132,000).

Program Benefits. The cost savings for smaller dischargers, while smaller in absolute numbers, have a large budgetary impact. For example, the smallest dischargers have a current, average annual monitoring budget of $246 and an average annual savings attributable to the Association of $11,707_a cost-savings factor of almost 50. Although the mid-sized dischargers have a greater annual savings, their current average annual monitoring budget is $51,064, yielding a cost-savings factor of 1.33. Also, the Association yields more reliable, useful data and studies deemed important to all parties.

Program Challenges.

- Who should champion the cause and organize members?
- Who should initially design the monitoring program_the permittees or the state?

Conclusion

In the last decade, groups have successfully used monitoring partnerships to address different problems and monitoring objectives as well as water bodies/ecosystems of differing scales_and have saved money in the process. The purpose of the monitoring programs has varied from water supply protection to coordinated, whole basin wastewater discharge management to ecosystem assessment. While case studies highlighted different approaches to setting up and maintaining a consortium, strong, common themes on program pitfalls and successes also emerged (see Table 2).

Watershed management is a continuing cycle of identifying, prioritizing, and working on key watershed issues. Well-defined watershed priorities depend on solid assessment of good information; good information depends on well-designed monitoring. Public and private agencies should incorporate strategic, coordinated monitoring into the continuing cycle.

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Conversation with Dale Crisp, LNBA Project Manager.

Authors' experience in designing and managing the TAWSMP & LNBA.

The San Francisco Estuary Regional Monitoring Program (RMP) was implemented in 1993 to support strategic basinwide water quality planning by coordinating NPDES permit compliance monitoring with comprehensive water column monitoring. The study area crosses 12 counties and covers 1,600 sq.mi. on the Pacific Coast of California. RMP conducts biological, chemical, physical, and sediment sampling at 25 stations throughout the region, with the objective of establishing a high-quality regional database that

can be used to determine use support; to conduct trend analysis and special studies; to better understand ecological structures and functions; and to identify problem priorities.

The Triangle Area Water Supply Monitoring Project began in 1988 as a supplemental, voluntary, monitoring program for drinking water source protection. The Triangle Region includes six counties and encompasses 3,320 sq.mi. within the upper Neuse and Cape Fear Basins in the Piedmont Province of North Carolina. The project conducts chemical, physical, and sediment sampling at 34 stations, both at water supply intake areas and their tributaries throughout the region. Its primary objectives are to conduct spatial and temporal water quality trend analysis and pollutant loading studies; to better understand the role of sediments in trapping and transporting SOCs; and to evaluate the condition of the source water.

As a component of North Carolina's basinwide management approach, the Lower Neuse Basin Association coordinates instream monitoring of 23 NPDES permittees at 42 stations along the 185-mile stretch of the mainstem river. The study area drains 4,807 sq.mi. in 15 counties of the state's Piedmont and Coastal Provinces. The Association conducts chemical monitoring with the primary objectives of determining the effectiveness of state-established total maximum daily loads and of better understanding the CBOD/DO relationship in the river and the relative contributions and impacts of nutrient loading.

- Establish watershed-wide consensus on the need for a coordinated monitoring program.
- Take advantage of existing organizations (particularly key leaders), as well as current and historical monitoring programs, to establish a strong foundation.
- Design a coordinated monitoring program that meets the collective and individual needs of the participants. For example, to the extent possible, ensure that the monitoring helps the regulated partners meet or offset permit monitoring requirements.
- Bring potential partners into the design and decision-making process early, and spread leadership.
- Design the monitoring program for continuity (to measure long-term trends) and flexibility (to adequately address emerging issues and priority concerns).
- Using a performance-based approach, design field sampling, lab analysis, or data management with flexibility and compatibility as your guiding principles.
- Adequately plan and budget for data collection, management, and interpretation. Quality assurance and quality control is essential for long-term program credibility.
- Clearly and regularly communicate the program's benefits for each partner and for the region.
- Regularly evaluate the monitoring program to make sure you are meeting the project's goals and objectives cost effectively and that you are adequately addressing emerging issues.

- Value the project's unquantifiable asset: the good working relationship you are building with consortium partners.

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Biological Monitoring Program Design to Address Questions at Multiple Geographic Scales: A Case Study

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Introduction

Prince George's County, Maryland covers an area of over 458 square miles and is adjacent to the District of Columbia on the east. The County is in the coastal plain physiographic province of Maryland. Streams in the County are divided among 41 watersheds and range from first to fifth order streams. Most of these streams are first to third order. The predominant land uses of the County are residential in the north and agricultural in the south.

Stream organisms are continuous monitors of both short and long term water quality and other environmental factors. Biological monitoring and assessment provides a direct measure of the ecological health of a stream. It can be used to detect impairment of the biological community and to assess the severity of impacts from nonpoint source (NPS) pollution. Over the past several decades, biological monitoring and assessment of aquatic communities has increased as has the application of these data to watershed management policies and practices. The County will use the benthic macroinvertebrate assemblage because monitoring this group provides a cost effective and ecologically relevant indicator of

stream condition.

Prince George's County currently uses a combination of chemical sampling, stream inspections, and a limited amount of biological sampling to assist in its environmental decisionmaking process. The development of the more comprehensive biological monitoring program is a significant contribution to the needs of Prince George's County to evaluate and manage streams in the County. The County is among the first in Maryland to establish a comprehensive biomonitoring program to assess the ecological condition of its water resources.

A multiple metric approach analogous to the Index of Biotic Integrity (IBI) (Karr etal.1986, Barbour etal.1995) and advocated by the U.S. EPA (Gibson 1994), will be used to analyze the biological data generated by this program. Potential metrics include richness measures (e.g., number of stoneflies, mayflies, and caddisflies), composition metrics (e.g., percent dominant taxon), and functional metrics (e.g., percent gatherers). Data generated by sampling reference sites will be used to determine which potential metrics are most suitable for use in evaluating the condition of streams in the County.

The monitoring program will coordinate with other ongoing monitoring programs in the region so that there will be increased benefits derived from data sharing, the use of joint reference sites and reference conditions, the ability to produce ecological assessments that are more regional in scope, and the potential for increased cost and time efficiencies. Comparability of methods and results will provide a stronger link to monitoring activities in adjacent counties (or other agencies), the District of Columbia, state monitoring and reporting activities, and national monitoring efforts. Two of these ongoing programs which Prince George's County will be most closely linked are: Montgomery County , MD, and the State of Maryland's Department of Natural Resources.

Program Goals

The purposes of the biological monitoring program are to assess the status and trends of biological stream resources (including the benthic macroinvertebrate assemblage and physical habitat quality) of Prince George's County. Additional purposes of the program (Table 1) are to relate the status and trends of the stream ecological condition to specific programmatic activities, such as BMP installation, stormwater permits, and guidelines for low impact development.

Table 1. The overall goal of the biological monitoring and assessment program and the secondary purposes/goals of that program.

Overall Goal: Develop and maintain a county-wide biological monitoring and assessment program
Purposes/Goals of Program

1. Document and monitor the biological status and trends of County streams
2. Integrate data from biological, chemical, and physical monitoring programs to make comprehensive assessment of the County's stream resources
3. Use biological monitoring data to identify and characterize impairment to the ecological system
4. Further public education in environmental problems through a component of the biological monitoring program tailored for lay-person involvement
5. Evaluate the effectiveness of environmental management and mitigation activities
6. Aid in development and support of comprehensive watershed management programs

Data generated by biological monitoring will allow the County to address questions regarding the quality of its streams on a county wide basis, in specific watersheds, and on a stream by stream basis. To meet the goals of the program, five categories of questions have been developed. This enables questions on all scales to be answered by incorporating targeted site-specific sampling sites as well as probalistic sites. These data will allow the County to document and monitor the biological status of the County's streams and determine trends in their condition. The County will be able to integrate the biological data with physical and chemical data to create a more comprehensive assessment of the County's streams and aid the development and support of comprehensive watershed management practices. As part of the larger biological program, the volunteer monitoring program will enhance public education and stewardship, increase public awareness of water resource issues, and foster greater public support for water resource management.

Types of Sampling Sites

Non-volunteer Program

Three major types of sites have been selected in the County. These are targeted sites, probability sites, and reference sites. Targeted sites include sites selected by volunteers based on volunteer interest (with County assistance to preclude overlap with County nonvolunteer sites), volunteer confirmation sites, and known problem sites. Probability sites have been selected in each of the County's 41 watersheds. At least two probability sites of each stream order will be sampled in each watershed. The minimum number was set according to a power analysis performed on data from the coastal plain streams in the state of Delaware. A total of 254 probability sites have been selected and will be sampled on a 6 year rotation (40 to 50 sites per period) during two index periods (early fall and early spring). A visual based habitat assessment will be performed at each site concurrent with sampling.

Targeted Sites

Targeted sites, selected to document the condition of an individual stream, are sampled by both the volunteer program and the nonvolunteer program. Known problem sites are selected for specific reasons:

to monitor effects of known problems such as discharges or habitat disruption, effects of remediation efforts, recovery, or in anticipation of future disturbance. Volunteer sites are selected by the County with the volunteer monitors based on specific interests in a stream such as its location in the volunteer's neighborhood, or to monitor suspected impairments. A subset of the volunteer sites, the confirmation sites, are monitored to confirm potential problems identified by the volunteer monitors. Approximately 20 known problem sites will be sampled for each index period.

Targeted sites are sampled semiannually during the program's two index periods. Trends are detected by comparing results to a previously established baseline and to decision thresholds. Determination of whether changes in condition (relative to a baseline) are real changes as opposed to natural variation, depends on how well the natural variability is understood (year to year and site to site). Data from targeted sites can document the decline or recovery of streams subject to specific stresses, and will allow assessment of restoration and mitigation efforts.

Reference Sites

Biological assessment relies on the comparison of data from assessment of test sites to a reference condition; the reference condition is based on a set of reference sites and serves as an objective standard of comparison (Gibson et al. 1994). Reference sites represent least disturbed conditions in the region. Criteria used to select reference sites include an abundance of natural vegetation in the watershed, especially riparian vegetation near the stream channel, the absence of known pollution discharges, stream alterations, and a minimum of roads, residential areas, and other human alterations (Hughes et al. 1986, 1994). A set of 15 to 20 reference sites will be sampled annually. The data will allow estimation of annual variation and trends in the biological characteristics of the reference sites.

Probability Sites

Neither individual targeted sites nor individual reference sites yield information that can be used to estimate status of stream resources in the county, nor in single watersheds. Conclusions such as "20 percent of stream segments in the County are impaired" require a representative sample of stream segments, which is best selected with a probability-based design. A probability based design usually includes some form of random sampling of sites, such that all sites have an equal probability of being sampled. This ensures the representativeness of the sample, in that a concerted effort is made to eliminate bias in site selection. The approach used to select these sites for Prince George's County was not simple random, but, rather stratified random.

Prince George's County was divided (stratified) into northern and southern watersheds, so that in any given year, an equal number of watersheds would be selected in the more urban north and in the more rural south. To allow the data analysis to detect upstream-downstream effects, and to avoid confounding headwater and larger streams in the analysis, streams were stratified by Strahler order. An equal proportion of stream segments of each order are selected in each watershed.

Site selection is basically in two stages: in the first stage, a set of watersheds are selected randomly, and in the second stage, stream segments within the selected watersheds are chosen at random for sampling. In each year of the monitoring program, a set of six to ten watersheds are selected (depending on size), and approximately 45 to 50 stream segments of those watersheds are sampled. After five years, all watersheds in Prince George's County will have been sampled, and in the sixth year the program will return to the watersheds sampled in the first year.

Volunteer Program

Volunteer monitoring is part of Stream Teams, an Adopt-A-Stream Program sponsored by the County. The program is divided into two (2) tiers. Tiers 1 and 2 are designed primarily to help develop community/citizen appreciation for local natural resources. Tier 2 also serves as a screening level assessment to help increase the density of sites that the County can use in annual status reports. Tier 1 is targeted for elementary to middle school age students and anyone else who has little or no experience in monitoring. Tier 2 is targeted for high school age to retirees. These latter groups generally have more experience in doing the fieldwork required for the assessments. The methods used by the Stream Teams are the same as those used for non-volunteer monitoring with some modifications.

Sampling Method

Since most of the County's streams lie within the Coastal Plain ecoregion, the main technique used to collect the macroinvertebrates will the "20-jab" method developed by the Mid-Atlantic Coastal Stream Workgroup (MACS 1993[draft]). A dip-net will be used to sample suitable habitats (e.g., snags and other woody debris, rooted vegetation) in the stream. For the transitional Piedmont, the double composite square meter kicknet sample (Plafkin et al. 1989) will be used.

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Developing an Applied System of Ecological Indicators for Measuring Restoration Progress in an Urban Watershed

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Introduction

Humans have been using ecological indicators of one form or another to evaluate their surroundings for hundreds, if not thousands, of years: an aching joint can suggest rain is on the way, a dead canary means it is time to leave the mine, and a shadow-shy groundhog is a forecast for six more weeks of winter. Ecological indicators have become a bit more formal and part of the establishment due in large part to efforts of the Environmental Protection Agency. Indicators have been used for years by EPA to monitor the administrative success of different programs. While these types of indicators provide insight into the potential for human impacts on the ecosystem, they offer no picture of the actual condition; the number of annual noncompliance events at facilities holding National Pollutant Discharge Elimination System (NPDES) permits is one example.

Attention has been focused more recently on developing indicators that directly measure the condition of the environment, and ongoing efforts span the spatial scale. EPA's Office of Policy, Planning, and Evaluation is developing national indicators for air, water, terrestrial ecosystems, and waste management (just to name a few; U.S. EPA, 1995); some of these indicators, such as stratospheric ozone decline, are global rather than national. The Chesapeake Bay Program has developed an extensive system of indicators covering the 64,000-square mile Chesapeake Bay watershed, with a heavy emphasis on the 1,100-square mile Bay proper. Although limited to five, the Tennessee Valley Authority presents indicators of water quality, sediment, and biological condition at numerous locations within each of 11 watersheds ranging between 1,370 and 5,140 square miles in size.

This study is more localized than the efforts mentioned above, focusing on the 176-square mile Anacostia watershed. The motivation and process behind developing a system of indicators for an individual, highly degraded urban watershed are discussed.

Background

The Anacostia Watershed

Located in Maryland and the District of Columbia, the Anacostia watershed is an ecologically diverse system that extends into two physiographic provinces (Piedmont and Coastal Plain) and contains free-flowing and tidal segments (Figure 1). Historically, the watershed was covered by temperate forest and contained extensive areas of tidal and nontidal wetlands. The river supported a rich fishery of both resident and anadromous species.

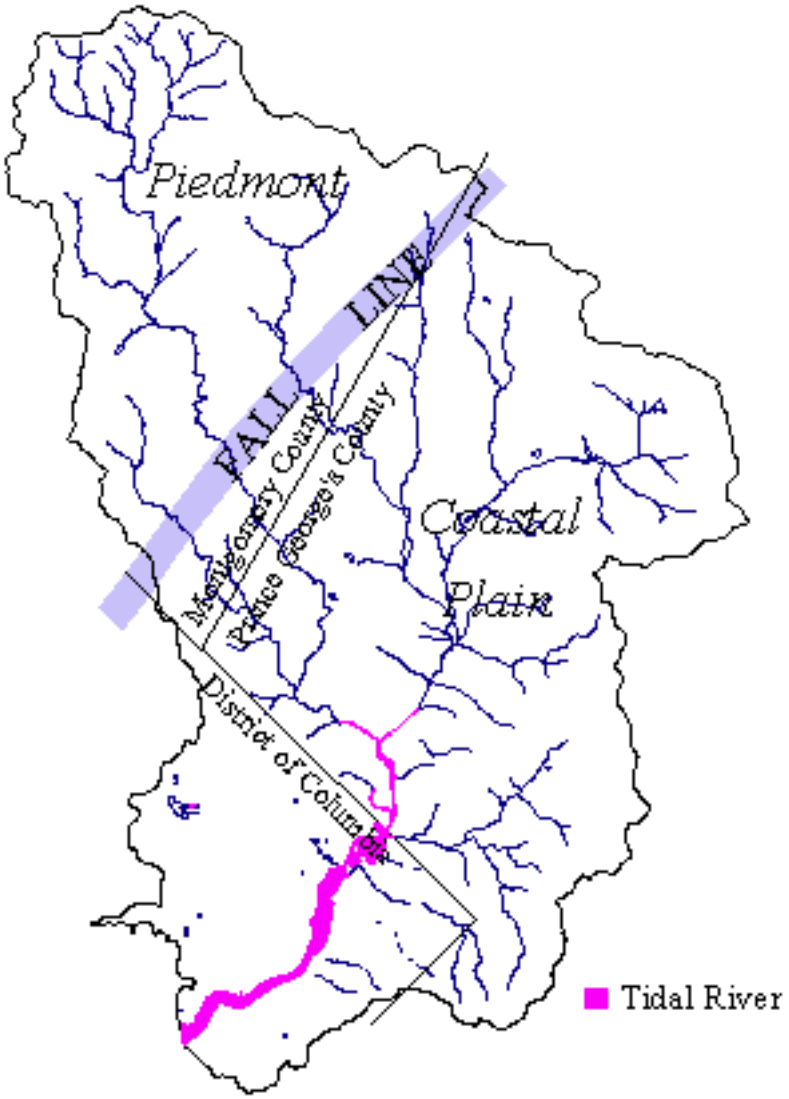

Figure 1. Anacostia watershed, Maryland and the District of Columbia.

The history of ecological degradation in the Anacostia watershed is long and varied, although for much of this century the problems have been a result of an expanding human population and the associated changes in land use and land cover. The loss of important forest and wetland habitat, alterations of streamflow, increases in nonpoint source pollution, and discharges of combined sewer overflow and industrial waste have all contributed to the decline in the ecological health of the watershed.

Summary of the Restoration Effort

Efforts to restore the Anacostia watershed began nearly two decades ago. Since that time, local, state, and federal government agencies, as well as environmental organizations and dedicated private citizens have contributed significant resources toward re-establishing as much of the original ecosystem as possible. Formal cooperation between government agencies came with the 1987, signing of the Anacostia Watershed Agreement and the formation of the Anacostia Watershed Restoration Committee (AWRC). Members of the AWRC include Montgomery and Prince George's counties, Maryland, the State of Maryland, the District of Columbia, and the Army Corps of Engineers as the federal representative.

During the initial years of the AWRC, the Committee coordinated implementation of projects throughout the watershed; the problems were abundant and many demanded immediate attention. The AWRC members concurrently recognized the need to establish a framework to guide a more lasting restoration effort. The vision was for an ecologically-based restoration of the watershed which, by 1991, took shape in the form of the Six-Point Action Plan (MWCOG, 1991). The Plan, which has become the guidance document of the restoration effort, identifies six goals that address the primary problem areas in the watershed (Table 1).

Table 1. Goals of the *Six-Point Action Plan* (MWCOG, 1991).

Goal 1: Dramatically reduce pollutant loads to the tidal river to improve water quality conditions by the turn of the century.
Goal 2: Protect and restore the ecological integrity of urban Anacostia streams to enhance aquatic diversity and provide for a quality urban fishery.
Goal 3: Restore the spawning range of anadromous fish to historical limits.
Goal 4: Increase the natural filtering capacity of the watershed by sharply increasing the acreage and quality of tidal and nontidal wetlands.
Goal 5: Expand forest cover throughout the watershed and create a contiguous corridor of forest along the margins of its streams and rivers.

Goal 6: Make the public aware of its key role in the cleanup of the river, and increase volunteer participation in watershed restoration activities.

Framework for Restoration

In December 1992, a series of work sessions was held to assess the status of the restoration effort in the Anacostia watershed and to identify program areas for future concentration*. During these work sessions, a consensus was reached that the goals of the Six-Point Action Plan needed to be refined in order to make them:

- specific, to individual subwatersheds and the tidal river;
- achievable, given a realistic assessment of the limits of our environmental restoration technology and existing conditions;
- measurable, using effective water quality, physical, and biological indicators of improvement;
- understandable, in terms that the public can readily and intuitively assimilate;
- flexible, so that they can be adjusted in response to new developments in technology, watershed research, or funding.

This effort to develop a system of indicators for the Anacostia is in response to the AWRC request that the goals of the Six-Point Action Plan be refined using the above criteria.

Developing a System of Indicators

Selecting Indicators

The difficulty in developing a system of indicators is faced when trying to select those indicators that most effectively represent the ecosystem in all its complexity. This problem can be minimized in two ways. First, a manageable advisory group (at least in terms of size) is created consisting of individuals with diverse areas of expertise. For the Anacostia effort, a technical oversight subcommittee (TOS) comprised of staff from the AWRC members was convened. Second, having a framework that identifies areas of concern provides a useful structure for establishing a system of indicators. The system of indicators for the Anacostia watershed is being developed within the context of the Six-Point Action Plan; that is, each of the indicators can be placed under one of the six goals in Table 1. An ecologically-based vision statement can provide the same type of structure.

The primary focus of the Anacostia indicators has been on direct assessment of the ecosystem, although some administrative indicators are being included. Further, the system for the Anacostia includes only indicators that are supported by existing data. The intent is to expand the system as monitoring changes (e.g., biomonitoring in the watershed is increasing). The method used in developing ecological indicators for the Anacostia watershed involved three general steps that are discussed below. Although in practice the process has been much more convoluted than this writeup suggests, moving through these stages produces a system designed to use currently available data to convey fundamental information on a watershed's condition.

Step 1. The first step in developing a system of indicators involves creating a comprehensive list of possible indicators through a series of brainstorm sessions. This list should be as extensive as possible, recognizing that a near-limitless number of indicators can be conceived. This is not a difficult process for a diverse group of experts, although knowing when to quit can be a bit more tricky. As a sampling, potential indicators identified in the Anacostia included water quality parameters (e.g., temperature, dissolved oxygen, total suspended solids, fecal coliform), pollutant loads, fish kills, trash, noncompliance of NPDES permits, sediment control violations, percent imperviousness, metrics from biomonitoring (e.g., relating to fish and macroinvertebrate populations or habitat condition), toxic concentrations in fish tissue, fish and wildlife utilization, bird counts, miles of modified stream channels, accessible range of anadromous fish species, wetland acreage (total and by type), forested acreage (total and by type), size and condition of riparian forest cover, the number of individuals receiving environmental newsletters, participating in stream cleanups, or volunteer monitoring, and dollars spent on restoration projects.

Step 2. The second step, which is a reality check in the process of developing indicators, involves determining data availability. Based on the familiarity of TOS members with and research into monitoring efforts, many of the indicators on the comprehensive list were eliminated as they are not supported by existing data. Those supported by data were placed onto a reduced list for further consideration. It should be noted that a tangential benefit of creating a comprehensive list is that it acts as a "wish list" for future monitoring efforts in addition to serving as a menu for possible indicators.

Step 3. The final step involved selecting indicators from the reduced list of data-supported parameters. This stage relies heavily on professional judgement and discussion of which indicators, individually and together, will best represent the overall condition of the ecosystem. In addition to professional judgement, four points were identified as needing consideration in the Anacostia:

- Tidal and Tributary Issues. Significantly different problems exist in the tidal and tributary portions of the watershed. Although the individual tributaries also have unique problems, these differences do not warrant creating separate indicator systems for each subwatershed.

- Administrative and Environmental Aspects. The system should include indicators that measure administrative as well as environmental progress.

- Short- and Long-Term Concerns. The time required to solve different problems varies widely, and

the system of indicators should address concerns that are both short-term (turn of the century) and longer term in nature.

- Improving and Static/Deteriorating Conditions. The system of indicators needs to be able to identify areas of improvement as well as continuing areas of concern.

There is the temptation to develop an indicator simply because data have been collected for a given parameter. The major pitfall of this approach is that funds are allocated to develop and track indicators that are either not be the most effective in describing the condition of the ecosystem or may have a very limited audience.

Presenting Indicators

In addition to offering the means to track restoration progress, indicators are used for education and outreach efforts, typically to the general public and elected officials. The basic purpose of presenting an environmental indicator is to communicate the condition of an important component of the ecosystem in a summarized form to a given audience.

While there are a number of ways to present indicators to an audience, the basic layout chosen for Anacostia indicators is very similar to that used by the Bay Program. This consists of a graphic such as a bar or pie chart accompanied by a few bulleted text items that are relevant to the indicator. For example, a bar chart showing an annual increase in submerged aquatic vegetation acreage could be supported by a bullet discussing an increase in secchi depth readings over the same time period.

Finally, while all of the indicators selected for the Anacostia are supported by existing data, some are not supported by historical data; that is, only one year of data are available resulting in a presentation of a status rather than a trend over time (Figures 2 and 3). These types of indicators, such as total and riparian forest cover presented in Figure 2, were retained in the system as it is expected that these types of data will be collected in the future.

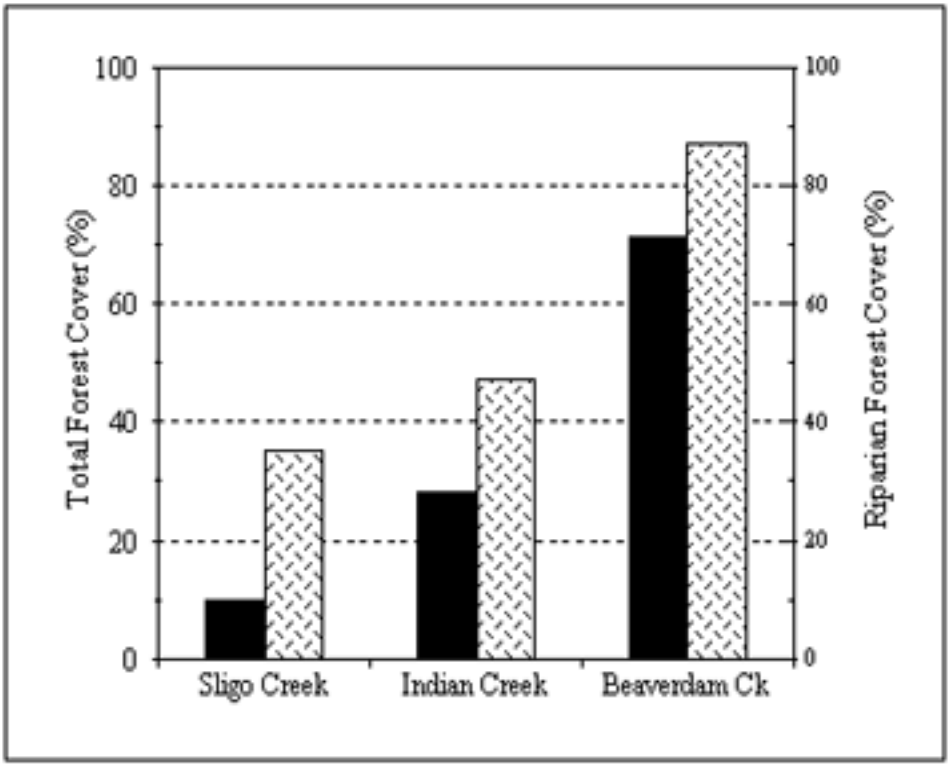

Figure 2. 1990 forest cover in select subwatersheds of the Anacostia.

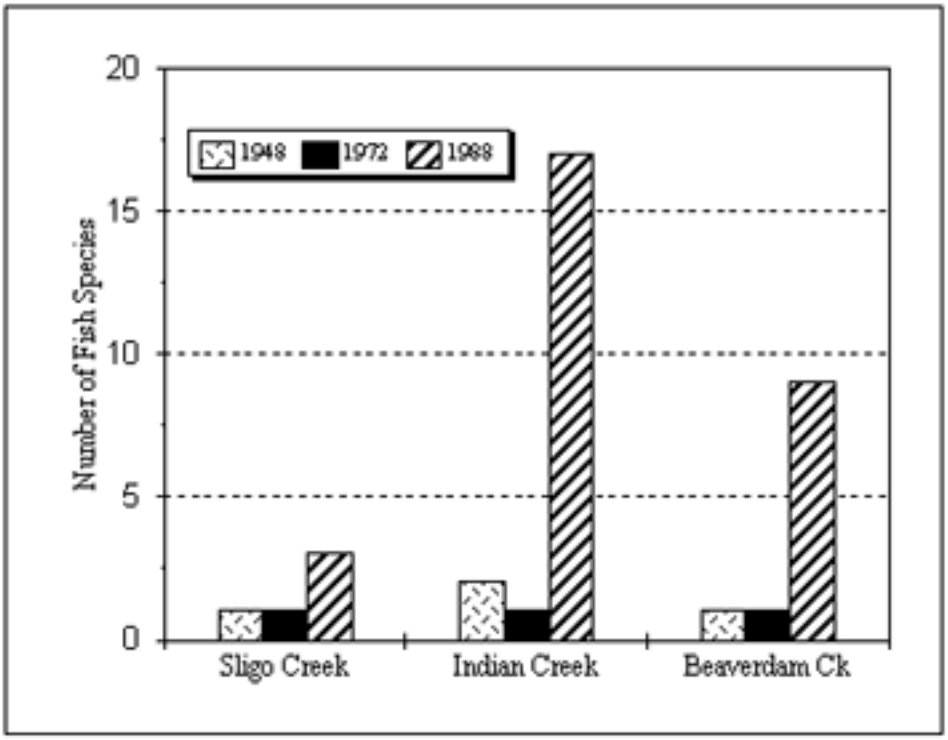

Figure 3. Historical counts of fish species in select subwatersheds of the Anacostia (Cummins, 1989).

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Citizen-Directed Watershed Management: The Oregon Experience

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In the early 1990's, Oregon natural resource managers took a new look at how its watersheds were managed. Watershed and public lands management in Oregon was often conducted in a convoluted fashion, managed by distant authorities and embedded policies, and conducted separate from local institutions. Project actions were implemented largely by agency funding schedules, rather than environmental urgency and need.

Watershed managers were often frustrated that management actions were largely confined to agency ownership boundaries, and generally not extended to neighboring private lands. Project actions were typically not coordinated across agency boundaries. The effectiveness of watershed restoration actions was considerably limited by the construction of legalistic, rather than natural watershed boundaries. The alternative was to integrate agency efforts and to incorporate neighboring (private) landowners into holistic watershed management.

To do this however, would require shifting some responsibility for watershed management outside the agencies. A series of state-wide water resources planning forums were held to discuss future policy, and a general consensus emerged that was encapsulated into the 1992 Watershed Management Strategy for

Oregon. The strategy was later codified as HB 2215 in 1993, which promoted the concept that (1) local governments should form voluntary local watershed councils, and (2) the councils would be cooperative partnerships of individual, local, state, and federal interests.

The Development of Citizen-Based Councils

Several different models and concepts for organization of watershed management groups evolved: (1) a basin-level "Model Watershed Area" in the Grande Ronde Basin, (2) a basin federation of local watershed councils in the Rogue, and (3) separate subbasin councils in other basins.

The state of Oregon's early attempts to assist councils involved staff being directed by state agencies from the Capitol. Recent efforts have focused more on local autonomy where staff are assigned to work for the local councils instead of state or federal agency programs. Both state agencies and environmental interests were initially fearful of fostering local control of watershed administration. However, most administrators now would say that all the Oregon councils reviewed have turned into responsible stewards_focusing on what they could make work in their particular situation_once they worked though the conflicts in the birthing process.

The Grande Ronde effort was largely driven by Endangered Species Act concerns, which threatened the traditional economic base for the region and unified agencies and private landowners in restoration efforts. Administration and planning was initiated at the basin level, then broken down to separate subbasin efforts for project implementation. In the John Day Basin, efforts to maintain a basin wide council have been put on hold and council efforts have focused on one subbasin, centered around salmonid habitat restoration activities.

In southwest Oregon, councils began as independent sub-basin groups, formed variously to address water quality issues (Bear Creek), forest management decisions (Applegate), economic development (Little Butte Creek), or fisheries management (South Coast). The state sponsored Watershed Health Program fostered two more councils (Evans Creek and Lower Rogue) to cover fire restoration areas and support local employment of displaced fishermen. The eight councils were linked through a Steering Committee supported by the Rogue Valley Council of Governments (RVCOG, representing three county governments) which provided the locus for regional oversight and coordination of natural resource restoration activities within the basin. Most of the councils also linked to Soil and Water Conservation Districts in their locale to include elected interests.

The basin-level unit of planning is appropriate if a superordinate problem is present throughout the basin (such as ESA or water quality requirements). However, where attempted, watershed planning and project actions among the Oregon councils have rapidly evolved to the sub-basin unit, while perhaps keeping basin priorities in reference. This trend suggests that ideally, watershed planning should be done on a multi-level basis, while implementation is more likely to be done at the sub-basin level. In each case, the local councils resisted administration and direction from state and federal agencies and sought to establish their own autonomy and authority. Although agency managers and many environmental

interests were skeptical that local boards would be efficacious in their management, most would now say that the local watershed boards and coordinators have proven to be conscientious stewards of their resources and responsibility.

The Process of Forming Councils

Early in the process, competing interest groups may jump to the opportunity to institutionalize their agenda into the council organization by attempting to influence the organizational structure formed. The most frequent interest group conflicts revolve around commodity vs. preservationist values, special species protection vs. multiple uses of resources, and agency administration vs. citizen directed councils.

Sponsorship is a key decision which establishes a long-standing precedent, on which the acceptance and survival of the local council may be dependent. Potential sponsors may include environmental organizations, commodity interests, federal or state natural resource agencies, or a division of County government. Sponsorship strongly influences staff structure and activities, public participation, the focus of environmental assessment, and the selection of projects.

Time and effort spent to formalize an administrative Board is an important part of the birthing process. Each of the councils reviewed suffered one or more re-organizations. It is important for local participants to go through a process of defining and developing consensus on the common interests the council is to address, align and balance special interests, and acquire agreement on policy and objectives. Resolution of differences that arise in this phase of the organization enlarges the base of consensus and legitimacy of the council, and allows the groups to 'work through' differences that would emerge later in the process. This phase can consume a calendar year of time or more.

Time will provide an excellent test of the importance of baseline funding for watershed council viability. The Grande Ronde was funded for program development by federal and state agencies/programs to create a professionally managed program. Most other basins have received only start-up funding from the State. A collection of councils were started with State assistance in the Rogue/South Coast, and given a considerable amount of money for project implementation, long before the councils had developed the organizational capacity to effectively implement programs. Now that the councils are organized, state support has shifted to other programs, with only sparse funding for new councils and projects throughout the state. A result of this practice is that councils with lay administrators must expend a major portion of their energy simply to provide funding for day-to-day existence, rather than building a viable program and organization. Interest in, and support for these marginal operations can rapidly dwindle, right at the time that they are developing potential for effective project action. The state has recognized this problem, and is seeking to develop alternative funding mechanisms, but most councils are underfunded.

Incorporating Stakeholders

Council viability hinges on obtaining participation from most of the key players (agencies, organizations, individuals). Getting agencies involved in an integrated watershed process is time consuming and

complex. Agency and tribal programs are frequently so institutionalized that it is difficult to break their traditional pattern to include them in a cooperative effort. If it's not clear to them how their agenda can be clearly forwarded by participation, they often do not make a strong commitment. However, projects seem to assist in breaking down inter-organizational barriers, refocusing energies, and developing a sense of local ownership and control.

Having at least modest implementation funds greatly enhances getting private landowners involved. Programs that have focused on extensive planning without linking the process to project implementation have not been successful.

Tasks for Watershed Management Councils

Watershed Assessment and Action Plan

The authors believe that one of the first activities a watershed council should undertake is to prepare a roadmap--a watershed assessment and action plan to identify, justify, and guide future activities. The Oregon Watershed Health Program required local councils to complete an assessment and action plan. Under Oregon's new watershed program, those councils who have completed them will use them to garner additional federal and state funding.

Ideally, the action plan should be a dynamic working document, intended to be updated, revised, and expanded as progress is made in implementation. The plan is a means to an end, however, and should not be allowed to become an end in itself. It is extremely important that key stakeholders (agencies, individuals) develop a sense of ownership in the plan as it is being created and modified so that implementing it is important to them.

The Oregon experience so far does not bode well for the future of action plans. If not required by funding agencies, they are difficult and costly to develop and maintain. It is often difficult to convince natural resource agencies to integrate and merge their formally mandated plans into the citizens directed planning effort, and inevitably, some dualism has remained in planning efforts.

Forming a Technical Advisory Committee

Technical committees not only provide critical knowledge and insight from multiple agencies and interest groups, they also broaden the potential representation base among stakeholders. Most councils formed a technical advisory committee as one of their first activities, to incorporate local and agency technical expertise into the evaluation and study process. Most councils have kept technical functions (residing in a technical committee) and policy functions (residing in a board of directors) separate.

Project Implementation

Oregon has yet to hit a "happy medium" in determining the scale of watershed restoration efforts. Most council watershed efforts have been funded for rather short terms, with only promises for long-term support. The short-lived Watershed Health Program focused on two areas of the state with far more money than could be efficiently spent in the two year period allotted. Watershed restoration is a long-term proposition. What is needed in most basins is long-term operations and technical support along with a modest annual amount of cost-share implementation funding. Continued communication and cooperation across agencies can lead to strengthening and expanding partnerships allowing many projects to be pursued collectively that can't be accomplished individually, especially in an era of shrinking budgets.

Clearing House Function

There is a mountain of environmental information in every watershed, but most of it unorganized, incomplete, or not amenable to easy retrieval. Interagency cooperation can be fostered by the council serving as a 'clearing house' to collate and disseminate information about basin wide environmental actions. The council gains legitimacy when it can serve as an information source to agency technicians. This effort can be relatively inexpensive, performed only periodically, and simple in design and presentation, but immensely valuable to other resource managers. Sharing information on concurrent actions also helps to frame the context for basin watershed management, eliminate duplication, and can be used to provide justification for project actions.

Sensible as a clearinghouse sounds, not one has yet been established in Oregon. Again, a major problem seems to be breaking agency inertia, and funding staff time for the effort.

Monitoring, Evaluation, and Environmental Assessment

There are typically two types of monitoring focus: (1) baseline conditions, to enable the measurement of future change; (2) measurement of the effects of project actions.

Most project implementation funding in Oregon has required some degree of project effectiveness monitoring. However, monitoring and dissemination of information has been spotty at best. An even more difficult problem is baseline monitoring , which requires years of technical data collection and staff effort. Extended baseline monitoring within a watershed seems possible only with integrated interagency efforts. Even then, it's sustainability in an era of declining budgets may often depend upon agency willingness to cooperate with volunteer efforts.

One of the most effective monitoring programs in Oregon is in the Bear Creek Watershed in the Rogue basin where the council has been measuring and gathering water quality data for the past decade. Such data has been used to justify funding for non-point source control and restoration actions and stream structure modifications that could never have been justified without supportive data. This program has probably been successful largely because of the RVCOG's many cross-agency ties and stability of leadership which has provided an extensive institutional memory and sense of direction.

Conclusions:

- There is a need to refocus watershed management around local councils that can integrate agency and organization programs and more effectively involve private landowners.

- Once organized, local citizen-driven councils have demonstrated that they can become responsible stewards, and address resource agency goals and interests as well as stakeholder interests.

- Councils either directly, or through a federation, should keep a basinwide perspective in planning, while focusing program implementation efforts at the subbasin or watershed level.

- Key stakeholders, both organizations and individuals, must be incorporated into council leadership and programs, and a common sense of ownership developed.

- Action plans, including resource assessments, must be developed and maintained at the watershed level. Landowners need to participate in their development, and agencies need to commit to assisting in their development and updating, and to using them to guide activities.

- All stakeholders need to cooperate in data acquisition and management. Volunteers should be professionally trained and used in monitoring efforts. A basin clearinghouse should be established for collection and dissemination of information.

- Councils should be provided with long-term funding for operations and cost-shared projects_preferably from a variety of sources. This serves to increase ownership by multiple stakeholders in the outcome.

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Lake Roosevelt: Successes and Failures in Building Partnerships

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Lake Roosevelt is a 130-mile long impoundment of the Columbia River behind Grand Coulee Dam in northeastern Washington. It provides power as well as flood control, irrigation, and recreation. The lake and its watershed draw nearly 2,000,000 visitors annually. This resource is managed by two tribal nations, three federal agencies, four state agencies, six sets of county commissioners, and is of interest to several citizen organizations. Needless to say, the average citizen is unsure of who to talk to about lake issues, of which one of the most contentious is water quality. The lake's water quality has been degraded by years of industrial waste from Canada. Lead, cadmium, dioxins, and furans have all, at times, been deposited in the Columbia River. With the creation of the lake, silting has caused potentially toxic levels of these pollutants to accumulate. Because of the multiple jurisdictions, a visitor to the lake may be unsure of where to legally fish, what licenses are required, and whether or not to eat the fish they might catch.

There were two groups working on these and other issues affecting Lake Roosevelt. The Lake Roosevelt Forum (Forum) was voluntarily organized by the jurisdictions responsible for the management of the lake and people using lake resources to provide a way for people to learn about proposed management activities early in the process and to seek common ground on how to promote a unified vision of Lake Roosevelt and its watershed. A second organization, the Lake Roosevelt Water Quality Council (Council), grew out of the Forum effort. The Council was formed by the US Environmental Protection Agency (EPA) and Washington's Department of Ecology (DOE) to organize a water quality study and to develop a water quality management plan. The results of these two efforts have been quite different, even though the players are nearly the same in each organization. The Forum is successful and growing. The

Council has achieved a set of "on paper" outcomes, but only after a lot of pain and dissension. The stakeholders were the same. The issues addressed were almost identical. The reason for this difference lies in the organizational development--especially groundrule development--of the two efforts.

The Forum was organized around a vision--dialog will lead to common understanding and trust which allows progress. Roles, responsibilities, and decision making were all decided by the stakeholders and embodied in a set of groundrules for how the Forum would operate. The groundrules provided the basis for development of the agreed upon outcomes of the Forum. Participation in Forum meetings and events has been a positive experience for citizens and professional managers alike. The Forum's committees have been active in involving many stakeholders and implementing decisions. The Emergency Services Committee has developed working agreements among all of the emergency service providers (fire, police, medical, etc.) to provide coordinated services across jurisdictional lines. The Fisheries Committee has developed a net pen fish rearing project and reviews power supply system proposals for Bonneville Power Administration. The Washington Governor's Council on Environmental Education is piloting a watershed education program on Lake Roosevelt in cooperation with the Forum. Forum members garnered $1 million in federal support to study the pollution sources and affects in Lake Roosevelt. This last effort led to the formation of the Council under the auspices of EPA and DOE.

The Water Quality Council is a study in contrasts. The Council was organized around a specific outcome, that is, directing a water quality study of Lake Roosevelt with a budget of $1 million over three years. The organizational structure was articulated by DOE and presented to the Council. A management committee made policy decisions, a technical advisory committee focused on the specific study elements, and a citizens committee coordinated community involvement. Although the titles were given, the development of groundrules, defining the roles, responsibilities, and decision making functions was left undone. Power struggles among citizens and agency representatives erupted almost immediately. Citizens demanded a role in the decision making process. It was nearly a year before the stakeholder members were able to take their seats on the management committee. Decisions were challenged at every step: Who has a right to participate? Who has a right to vote? Who can veto? Who is a stakeholder? Who makes final decisions? These questions caused conflict because there was no avenue to involve stakeholders equally in the process.

Equal involvement by all stakeholders is fundamental to the success of partnerships for watershed management. Involvement requires an individual's or organization's presence and visible interaction with others in the decision-making process. Many citizens seek to participate without their direct personal involvement. They want decision makers to hear their views and to recognize their influence without them having to confront those with other points of view. An individual can participate without being present--they can write letters or have an interest group represent them. In any case, it is important to recognize that citizen involvement in the development of public decisions is needed to ensure fairness and an acceptable collective decision about shared problems and solutions that can be implemented. Citizen concerns, views, hopes, and perceptions are critical to the development of a workable decision. A workable decision has three components: (1) The process of the decision making is seen as fair, (2) the stakeholders all have a say, and (3) implementation will not be impeded.

Fundamental to a good decision is the development of a process for fair and open involvement. Equalizing the power base for involvement requires that everyone know, understand, and share in the development of the groundrules. "If you don't know the rules, you can't play the game."

Groundrules are a set of agreements developed by participants in a collective decision making process. Groundrules identify what contracts, agreements, or expectations the group has for the proper conduct and behavior that will occur during their negotiations or problem solving efforts. Groundrules specify the group's procedural agreements of how they will conduct work and what minimum behavior standards and agreements are necessary for them to begin mutual risk taking and problem solving. The content of the groundrules is also of great importance as these decisions set the "rules of the game." These decisions include how decisions will be made, who will be participating, how data will be collected, how problem solving will be handled, and how conflicts will be managed.

The groundrules can be viewed as an essential first step as the participants begin to build the level of relationships and trust necessary to accomplish their tasks and to ensure implementation of their agreements. The very act of developing and agreeing on the groundrules provides an opportunity for the stakeholders to practice their problem solving skills before the "real" decisions must be made.

In the final analysis, because the perception of the Forum's process is fair and open, stakeholders continue to participate even though they may not always "get their way." The Forum is growing in influence--taking on new projects. The Council has faded as the $1 million was spent. The Council has now become a Water Quality Committee that meets as a part of the Forum's regular business meetings. The difference in perceptions toward the two organizations occurred because there was a difference in the equality of involvement by all stakeholders and in the development and use of groundrules. For success, development of a structure that is inclusive of all interested stakeholders, as well as the joint creation of groundrules must be planned for during the very first organizational steps of watershed action groups.

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Implementing Environmental Justice in Water Quality Programs

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Although poison runoff, and more generally environmental degradation, in one way or another affects every Clevelander, not every community in Greater Cleveland is affected in the same way. In particular, the information and economic needs of the African-American community are overarching concerns that shape the community's experience of water pollution problems. The three areas of concern regarding water pollution from an African-American perspective are: (1) access to information; (2) communication and outreach efforts; and (3) advocacy. We describe each of these needs and concerns briefly below.

Information Needs and Economic Linkages

There is a definite need for water pollution information tailored to the conditions of inner-city communities. Nationwide, a few dozen studies in the Environmental Justice field have examined the relationship between environmental issues, in particular toxic waste dumping, and race and/or income levels of the surrounding communities, but none of these studies have made water pollution their primary focus. The relationship between ethnic and income group distribution and poison runoff and impaired waterways is little understood.

Since economic development and reinvestment issues are central to inner-city communities, there is a critical need to link information on water pollution and waterway restoration to the economics of community development in urban areas. In our talks with the late Omar Ali-Bey of the Denise McNair New Life Center on Woodland Road, the need for jobs was central: "Water pollution education has no meaning unless jobs are tied into it." Harllel Jones, also of the Denise McNair Center, further stated that jobs, and not job training, are needed by Cleveland's unemployed people. "We don't need training," said Mr. Jones, "we just need to get hired."

Government investment in "Brownfields" strategies for reindustrialization was also highlighted by Harllel Jones, who particularly emphasized the need for investment in "black-owned firms."

East Cleveland School Board member Emma Whatley linked water pollution work with the creation of new careers: "Our children need to be given the understanding that problems like water pollution may be an opportunity for a career. We need more environmental programs in the school." Thus, further research into jobs and career development for youth in environmental professions, is of critical importance to the success of environmental cleanup programs in Greater Cleveland.

Communication

There is a need for much broader contact between urban watershed restoration and pollution control professionals and people of color and disadvantaged communities throughout Greater Cleveland. Traditional communication modes that work well for highly-educated, already-involved activists, consisting of newsletters and the occasional public hearing or meeting, do not work well as communication modes for residents of lower-income and minority communities. Perhaps most disturbing from a public involvement perspective, there are few opportunities for water quality officials to interact routinely, and directly, with the diverse community leaders of Greater Cleveland. In the Mill Creek Watershed, there has been more interaction between community leaders and water quality officials from the Northeast Ohio Regional Sewer District (NEORSD); there remains a need to bring in other neighborhoods that do not have a direct agenda for watershed development at this time, but who nonetheless need to know about sewerage issues affecting them. This is a communication challenge not only for NEORSD, but for all water quality officials and activists. Indeed, all major players in water quality issues need to expand and improve outreach and communication with communities of color and lower-income neighborhoods, and to involve them in environmental policymaking and planning projects within Greater Cleveland.

The form and content of public hearings, the setting of environmental priorities, and the process of consultation with "local stakeholders" can and should be opened up farther to non-traditional, diverse voices. These voices and views must be incorporated into watershed restoration and cleanup decisions. Issues including development and pollution permits, impairment of Cleveland's waters by combined sewer overflows (CSOs), fish contamination, sewer line installation, watershed restoration planning, landfill leachate, and point source pollution from factories and sewage plants all directly profoundly affect communities of color. Public officials charged with addressing these issues need to work harder to tailor their communications and public input processes to the viewpoints and concerns of these diverse communities.

Through its work with the Cleveland: Heal the Waters Project, the Minority Environmental Association (MEA) took some initial steps to begin to fill this communication gap concerning water quality issues. Through public speaking and one-on-one meetings with leaders, MEA established a basic awareness of urban water pollution problems, including CSOs; landfill leachate; and broken sewer lines, among

neighborhood and citywide groups in Garfield Heights, East Cleveland, and other communities. This work needs to be expanded and continued in a myriad of ways and through a variety of outreach groups in Greater Cleveland. An example of an ongoing program that establishes broader "watershed awareness" is the GREEN project that teaches high school students to conduct water quality monitoring studies and to communicate their results to the public.

On the Need for Watershed Advocacy and Environmental Jobs in Minority Communities

There is a great need to broaden the spectrum of people involved in addressing urban water issues. The lack of diversity among citizen advocates active in the Cuyahoga River Remedial Action Plan and other regional watershed restoration efforts results in frequent "preaching to the choir" and insufficient building of an informed citizen leadership. The two concerns outlined above (the need for information-gathering and better communications that are tailored to minority and disadvantaged communities) have in turn led to this dearth of diverse water quality advocates.

A clear, well-defined linkage to jobs and career development is an added motivation for neighborhood and youth leaders to take interest in Greater Cleveland's water pollution problems and solutions. As watershed awareness grows, so does awareness of job opportunities linked to watershed restoration. In the words of one environmental educator, Sandi Crawford of Zuyahoga Community College (Tri-C), "an environmentally informed community can find ways to share in the economic benefits of restoring some of the problem areas." Tri-C has established a Center for Environmental Education and Training, and an Environmental Equity Institute, to help make the jobs-environment linkage through environmental career development programs.

In the vision of one Cleveland watershed activist, Mary Beth Binns of the Cuyahoga River Community Planning Organization, Tri-C's Center for Environmental Education and Training holds the potential to catalyze or provide watershed jobs for youth in recycling, streambank stabilization, and other environmental cleanup and restoration work. These youth jobs could be housed in the Neighborhood Opportunity Centers of the Council for Economic Opportunities.

The only way that knowledge can make a change in people's lives is if it leads to action. The motivation for action stems from a greater awareness that all Clevelanders, including African-Americans, depend upon clean and safe water in everyday life. One example is people who fish in Cleveland's waters. We were particularly impressed with the love of some Clevelanders for fishing in Lake Erie, off of the 55th Street pier. The "55th Street Anglers" illustrate the importance of clean water to Clevelanders, and the concern that many have over the everyday pollution caused by poison runoff and other discharges. The anglers talked with us about fishing and water pollution, and expressed a strong personal connection with local water quality through their fishing experiences.

Recommendations

Growth Management for Watershed Restoration Must Be the First Priority

The more Cuyahoga County and surrounding communities allow uncontrolled growth to occur, with its endless roads, rooftops, and parking lots, the tougher will be the job of healing the waters. If strong environmental planning concepts are not applied in Greater Cleveland, the poison runoff loadings from newly-developing sites could eventually dwarf the current runoff loadings estimates, and dead and dying urban streams will have no chance of revival. Growth management, and particularly water-sensitive site design and master planning requirements, must be the first priority.

Water Quality and Watershed Restoration Strategies Should Emphasize Jobs and Economic Development

Inner-urban watersheds are often zones where joblessness tends to be high. In order to maximize local community support, energy, and enthusiasm for restoration projects, local and state environmental officials need to link restoration strategies to job creation and economic development. Such jobs could be as diverse as tree-planting, catch-basin cleaning, sewer-system monitoring, and land-cover mapping. Local Civilian Conservation Corps crews could be deployed for some of these projects. Organizations like Build Up Greater Cleveland and programs like Tri-C's Center for Environmental Education and Training, could help to fundraise and strategize among business and industry leaders. In addition, any "Brownfields" reindustrialization strategy for Greater Cleveland needs to include watershed restoration objectives.

Local Environmental Programs Must Give Greater Emphasis to Runoff Prevention

We strongly recommend that tried-and-true stormwater prevention measures be implemented in Cuyahoga County and Greater Cleveland immediately. These include zoning code changes to require water-sensitive site design for new development. Other less-mature measures, such as parking lot runoff storage, should begin to be implemented on a phased-in basis throughout the region. Runoff capture measures in the urban core, combined with water-sensitive site design and infilling strategies for new development, can slow down increases in poison runoff loadings from new development in the region.

Stormwater Solutions Must Be Integrated With Other Programs and Coordinated Across Whole Watersheds

Poison runoff solutions must be integrated with other planning policies in Greater Cleveland, including growth management, air quality, and transportation plans. Civic leaders have begun to shape whole-watershed strategies for the lower Cuyahoga River, Doan Brook, Mill Creek and other local waters. Suburban and inner-city developers and officials must work together for strategies that combine

preservation and restoration in these projects. In addition, one single agency needs to be responsible for coordinating zoning code changes for storrnwater prevention site design throughout major watersheds in the region.

NEORSD Should Include Stormwater Management Measures in its CSO Permit, Slated for Renewal This Year

NEORSD should be willing to be accountable for creating and implementing measurable performance and implementation objectives for both CSO and stormwater control and reduction measures in its CSO permit, even where EPA policy and guidance stops short of establishing such objectives.

For example, some of the more "mature" stormwater solutions, such as roof drain disconnecting should be explicitly integrated into the "Nine Minimum Controls" listed in NEORSD's forthcoming CSO permit, attached to objective, verifiable application standards.

Citizens in Greater Cleveland Can Participate in Poison Runoff Prevention in Many Ways

Citizens seeking to stem the flow of poison runoff and raw sewage in Greater Cleveland have an opportunity through the issuance by Ohio EPA of a renewed CSO permit to NEORSD. Citizens can begin by exercising their right to comment on the draft permit, especially regarding which waters are local priorities for CSO elimination or reduction.

The citizens of Greater Cleveland, and all of Cuyahoga County, need to become involved in existing small watershed efforts, such as the Doan Brook and Mill Creek projects, and to give input into the Clean Water Act's National Pollutant Discharge Elimination System permits issued to Cleveland-area factories, sewage plants, and CSO systems by Ohio-EPA. The best way to do this is through joining an existing citizen group, such as the Earth Day Coalition and the Lake Erie Alliance, and becoming active in a committee of the Lower Cuyahoga Remedial Action Plan.

Beyond participating in community and regulatory programs, citizens can take individual action to reduce runoff by landscaping their yards to hold and infiltrate more rainwater, recycling motor oil, driving less and supporting mass transit to reduce the need for parking lots and roads, and supporting the development of compact, energy- and land-efficient communities.

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Private Property Rights...Principles, Perceptions, and Proposals*

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Over the past few years, protecting constitutionally guaranteed private property rights hasbeen a rallying cry among many people who are concerned about increasing environmental regulation. Perhaps no single issue has propelled this debate as has the protection of wetlands. Using wetlands regulation as a focal point, this paper will examine the historical bases of constitutionally guaranteed private property rights, the federal courts' interpretations of when a compensable taking has occurred (and when it has not), and the most recent legislative actions that address private property owners' rights under federal environmental regulations.

> ***"...the passions created by property are keenest and most tenacious..."***
>
> **--Alexis de Tocqueville, Democracy in America, (1835)**

Wetlands are caught in the crosshairs of the inherent conflicts found within the bundle of rights that we expect in this country. People expect both the unfettered right to use their land, as well as the right to use and enjoy unpolluted waters.

One of the reasons that the wetlands debate is so contentious is that it affects directly individuals, not just corporate America. Two decades ago, the "regulated community" generally included only corporations and municipalities. In contrast, federal and state laws that prevent the destruction of wetlands impinge on the traditional notions of land ownership and use, and as such affect the millions of people in this country who own the approximately 75 million acres of wetlands in private ownership in the contiguous U.S. In a country where property ownership is a fundamental, constitutional right, use of that property, unrestricted by federal regulatory requirements, is what some landowners are demanding. Alternatively, they argue that the Takings Clause, described below, entitles them to compensation for any more than a minimal

reduction in the value of their property should federal regulations prevent them from engaging in certain activity on their property.

The Takings Clause, the Commerce Clause, and Wetlands

The Takings Clause

In 1791, the Bill of Rights, consisting of the first 10 Amendments to the U.S. Constitution, was ratified. The Bill of Rights, Article V, provides that "no person shall, among other things, be deprived of certain rights . . . nor be deprived of life, liberty, or property, without due process of law; nor shall private property shall be taken for public use without just compensation." U.S. Const. amend. V. The interpretation of this clause, commonly referred to as the "Takings Clause," determines private property owners' constitutional rights to compensation when the government "takes" their property.

Three years before the Bill of Rights, the Constitution was ratified, providing, among other things, that the federal judiciary should interpret the Constitution, as well as the laws enacted by the U.S. Congress. From the date of the writing of the Constitution until the 1920s, the U.S. Supreme Court generally interpreted the Constitution to address a physical taking or permanent occupation of the land in the Takings Clause. In Pennsylvania Coal v. Mahon, 260 U.S. 393 (1922), however, the Supreme Court recognized that regulation could be tantamount to a physical taking and justify compensation under the Constitution. Nevertheless, in writing the opinion for that case, Chief Justice Oliver Wendell Holmes stated, "Government hardly could go on if to some extent value incident to property could not be diminished without paying for every such change in the general law." So the Court held that regulation require compensation under the Takings Clause, but only in certain circumstances.

The Supreme Court ratified and reaffirmed those circumstances seventy years later when Justice Antonin Scalia, known as a strong conservative, noted and quoted Chief Justice Holmes in Lucas v. South Carolina Coastal Commission, 505 U.S. 1003 (1992). In Lucas, the Court revisited the regulatory takings issue and held what the Court had for seven decades: that the regulation of private property must be justified as a legitimate exercise of government action, and that justifiable regulation that "takes" all economically beneficial uses of the property entitles an aggrieved landowner to compensation. The Court stated, "We think, in short, that there are good reasons for our frequently expressed belief that when the owner of real property has been called upon to sacrifice all economically beneficial uses in the name of the common good, that is, to leave his property economically idle, he has suffered a taking." It is this interpretation that property rights advocates generally seek to expand.

The Commerce Clause

While the Constitution gives the courts the responsibility to interpret laws and constitutional issues, the Constitution gave Congress the authority to regulate a prescribed list of activities, including, "commerce with foreign nations, and among the several states, and with the Indian tribes." U.S. Const. Art. 1, section

8. The Commerce Clause of the Constitution has been interpreted to give the Congress authority to regulate activities affecting interstate commerce, which the courts have interpreted to include the regulation of waters used by interstate travelers for public recreation, waters used to irrigate crops and sold in interstate commerce, and waters on the flyways of migratory waterfowl.

Just last year, the U.S. Supreme Court refused to review and therefore let stand a Ninth Circuit Court of Appeals ruling that held that the use of seasonally dry, isolated wetlands (prairie potholes) by migratory birds provided a sufficient connection to interstate commerce to justify Congress' exercise of regulatory authority over those areas. (Cargill Inc. v. U.S., 116 S. Ct. 407 (1995). The federal courts also have determined that the Clean Water Act (CWA) should be given the broadest constitutional interpretation possible when considering its jurisdiction. It is these interpretations of the CWA and the Constitution itself that have given the federal government the authority to regulate wetlands under the CWA.

[No] person shall, among other things be deprived of certain rights ... nor be deprived of life, liberty, or property, without due process of law; nor shall private property shall be taken for public use without just compensation."

--The Bill of Rights, Article V

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"[W]hen the owner of real property has been called upon to sacrifice all economically beneficial uses in the name of the common good, that is, to leave his property economically idle, he has suffered a taking."

--Lucas v. South Carolina Coastal Council, 505 U.S. 1003 (1992)

Wetlands

When the basis for the wetlands regulation, section 404 of the Federal Water Pollution Control Act, was enacted in 1972, the authority to regulate wetlands was imprecise at best, and muddled at worst. Congress chose to require a permit for the discharge of dredged or fill materials into "navigable waters," and then defined "navigable waters" to include "all waters of the U.S." Relying on this language, in part, the federal courts in the mid-1970s interpreted "navigable waters" to include wetlands. The courts' interpretations, however, were not well received in all quarters. As a result, when the Federal Water Pollution Control Act was reauthorized in 1977 (and given the short title "Clean Water Act") the debate raged over the extent to which the CWA should regulate wetlands. The word wetlands was incorporated into the Act. Anyone who believes that the controversy surrounding wetlands is new need only look to the legislative history to see that the issues and conflicts are not new, only more visible.

Clash of the Clauses

Clearly, if the Commerce Clause of the Constitution, as interpreted by the courts, or the Fifth Amendment to the Constitution, as interpreted by the courts, were read without regard for each other or for the other provisions of the Constitution, we would have an irreconcilable conflict. In over 200 years, and under many, many changing circumstances, however, the courts have struck a balance. That balance has weighed the rights of private property owners with the responsibility of the government to protect public health, safety and welfare. This responsibility has included environmental protection.

Numerous cases have awarded compensation to landowners when they have been denied permits under section 404 to undertake activities of their choice. Nevertheless, many people and many Members of Congress believe that the judicial process is often too expensive and lengthy, or that the traditional constitutional protections, as interpreted by the courts, simply do not go far enough. These opinions are the genesis of private property rights proposals now before Congress.

The 104th Congress

The election of the 104th Congress, led by a core of conservative Republicans, has brought to a head the conflict between unrestricted property use, compensation and wetlands protection regulatory activities. The central principles of their agenda are outlined in the "Contract With America." The Contract states that "a private property owner would be entitled to receive compensation for any reduction in the value of property that is a consequence of a limitation on the use of such property imposed by the federal government" (emphasis added). The Contract provides specifically for "compensation for private property takings."

On the first day of the new Congress, four bills were introduced addressing private property rights, with more to follow. In hearings before congressional committees addressing these bills, proponents of the legislation argued the following:

- Property rights are under siege by government regulations, and courts have not gone far enough to protect private property.

- Obtaining compensation through the courts when a regulatory taking has occurred is cost prohibitive for most people, and takes too long.

- Expanding traditional private property rights protections will ensure that the government will fairly weigh the costs and benefits of its action, and only regulate those things really worth the price.

On the other hand, those who oppose the expansion of traditional private property rights by legislation make the following arguments:

- The Takings Clause does not prohibit the reasonable regulation of property rights to protect the public health, safety or welfare.

- The legislation would create a windfall if someone purchased property (i.e, wetlands) and then failed to get permits because of the environmental requirements. The costs of paying for every reduction in value resulting from government regulation will effectively stop federal programs to protect the environment.

- Changes that are needed to the wetlands or other environmental programs should be made to those programs, not in overarching legislation that could affect every conceivable government action.

In the House, the key legislative vehicle for property rights issues has been H.R. 9, the Job Creation and Wage Enhancement Act. H.R. 9 provides that a private property owner is entitled to receive compensation for a reduction in the value of property if the reduction is 10 percent or greater and is a consequence of "a limitation on an otherwise lawful use of the property imposed by a final agency action." The Act also establishes an administrative procedure for compensation whereby a private property owner may submit a request for compensation to the head of an agency that took the action. Within 180 days after the receipt of a request for compensation, the head of the agency "shall" stay the agency action and offer the property owner compensation. The private property owner has 60 days to accept or reject the offer, and may submit the resolution to arbitration if he or she rejects the offer. Payment for the diminution in value is to be made by the head of an agency to the private property owner based upon his or her acceptance of the agency head's offer, or a decision of the arbiter, within 60 days. H.R. 9 (as amended by H.R. 925, the Private Property Act of 1995) passed the House on March 3, 1995 by a vote of 277-148.

Several other property rights bills were introduced in the House last year, but, except as noted, they have languished in Committee and will not be taken up this year. H.R. 489 would expand the jurisdiction of certain federal courts to hear takings cases. It was considered in the course of hearings on H.R. 9/925 and was partially incorporated into that bill, as was H.R. 790, which would provide compensation if federal wetlands or endangered species determinations reduce property values by 50 percent or more. H.R. 971 would generally allow homeowners to seek compensation for the decrease in property values caused by others, such as developers and industry. Of greater significance, H.R. 961 strikes section 404 and creates a new program that allows anyone whose land is classified as a wetland of "critical significance" to seek compensation from the U.S. for any diminution in value. Other "non-critical" wetlands are generally opened for development. The bill passed the House by a vote of 240-185 on May 16, 1995 and was referred to the Senate Environment and Public Works Committee, which is expected to consider wetlands reform in late winter/early spring 1995.

In the Senate, Majority Leader Robert Dole (R-KS) sponsored S. 605, the "Omnibus Property Rights Act of 1995," which would require the federal government to compensate property owners if federal regulations deny them the use of their property or diminish its value by 33 percent. The bill was approved by the Senate Judiciary Committee by a 10-7 vote on December 21, 1995 and is expected to reach the Senate floor in late February or early March of 1996. S. 605 would allow landowners to receive the difference between the fair market value of the property before and after the government action. The bill also clarifies the legal standard for a "takings," encourages arbitration of claims, requires government agencies to consider whether their proposed action may lead to a taking and streamlines the administrative appeal and compensation process for claims arising under the Endangered Species Act.

Other bills which have been considered but not acted on in the Senate include S. 22, which would require that all federal agencies complete a private property taking impact analysis before implementing any action that is likely to result in a taking, S. 135, which would set out new judicial procedures for

compensation of private property owners if state or federal agency actions diminish the value of property by 20 percent or $10,000, and S. 145, which would provide compensation for reductions of 25 percent or $10,000 or more in the fair market value of private property caused by governmental action.

Conclusion

The current private property rights conflict is part of the larger national debate in which we are engaged. That debate includes issues such as where to draw the line between individual rights and responsibilities, and what the role of the federal government should be. How should we balance the rights of the majority, the minority and future generations? Rarely is there a clear or bright line on these issues. As we shift through the reasoning and rhetoric of the environmental pieces of this debate and try to craft rational policies that are fair to all, we must make some accommodation for the future and for our neighbors, without trampling on the rights of individuals who are here now. That very delicate balance has and ever will be shifting, as the

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Economic Considerations of the Restoration of a Tidal Salt Marsh: The Case of the West River

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Introduction

The West River and its flood plains occupy approx-imately 35 square miles in New Haven and West Haven, Connecticut. The West River has its headwaters just north of Lake Bethany and flows south almost seventeen miles to New Haven Harbor and on to Long Island Sound. Currently under consideration is a proposal to restore 70 acres of degraded wetlands located on the West River. Past experiences have shown that the reintroduction of tidal flows to a degraded system will restore the site to a productive salt marsh. The proposal, however, is not without controversy. Both the interest and the controversy revolve around the numerous effects from the main component of the restoration: opening the tide gates that are located where the river crosses Route 1 in New Haven. This paper examines the economic impacts associated with the opening of the tide gates.

The tide gates, installed in 1919, have substantially changed the ecosystem of this site. The gates act as a one-way valve, blocking seawater from Long Island Sound travelling upstream, and thus effectively prevent tidal mixing. This has substantially degraded the wetlands by reducing the salinity of the system, allowing Phragmites australis, an aggressive reed grass, to invade the marsh to the extent that it has become a complete monoculture. Phragmites crowd out both plant and animal species and are poor habitat for most types of wildlife due to their density. Water quality in the area has been degraded and the watershed, in its unnatural state, supports larger populations of mosquitos and ticks. Other man-made structures in the flood plain include the Volvo Tennis Center and surrounding athletic fields and planned future developments such as a biomedical park. The watershed is also home to the least tern, an endangered bird species.

As with any proposed restoration, there are winners and losers. In order for an objective analysis to be completed, as many players as possible must be included in the study. Affected parties of the salt marsh restoration include riparian land owners and developers, recreational users and wildlife. Much of the difficulty associated with evaluating a salt marsh restoration stems from those impacts that do not have a market price. In other words, value is not determined or set by the market. For example, the valuation of wildlife habitat in the West River watershed is a difficult, but crucial component to this analysis. Although they have a significant value to the public, they risk being excluded entirely from economic analysis and the decision-making process. This is due to their non-market nature, which, on the surface, gives them the appearance of having no economic value. Such a conclusion could result in distorted and environmentally unfriendly policy decisions, in the words of one economist, ". . . the systematic relocation of the most environmentally risky activities to the most pristine environments." (Hutchinson et al., 1995). For this reason, we have chosen to focus the study on the monmarket benefits and costs of restoration. In particular we focus on habitat preservation for the endangered least tern. This paper presents the survey design for a valuation of wildlife habitat in the West River watershed. We find the potential for significant nonmarket benefits from the proposed restoration.

The Contingent Valuation Method and Wildlife Resources

Estimating the benefits of nonmarket goods and services, such as the preservation of endangered or threatened species, has proven to be difficult and controversial. Since Krutilla, 1967, first defined existence value, economists have debated valuation techniques. Under the assumption of weak separability of preferences (nonmarket from market goods), a "pure existence value" can be determined (McConnell, 1983 and Madariaga and McConnell, 1987). The most widely recognized method for the valuation of nonmarket goods and services (including those with existence value) is the contingent valuation method (CVM). The contingent valuation method is a technique which uses surveys to elicit "willingness to pay" (WTP) for nonmarket environmental amenities or proposed programs. (See Portney, 1994, Cummings et al., 1986 and Mitchell and Carson, 1989 among others, for a thorough examination of the methodology).

Using CVM to value wildlife is not a new phenomenon. CVM has been used in several studies on endangered species (see for example, Stevens, et al. 1991, Boyle and Bishop 1987, Samples, et. al., 1986, Hageman, 1985, Stoll and Johnson, 1984 and Brookshire et. al, 1983). Other studies have focused more generally on wildlife preservation (Stevens et al., 1994 and Desvousges, et al., 1993 , for example). However, the results of these earlier studies are not without controversy and some are seriously flawed due to poor survey design. The studies are similar in that they attempt to elicit WTP for wildlife (endangered or not) preservation, but the actual object to be valued (e.g. a species, a number of animals or a change in the probability of extinction or habitat) varies. These earlier studies also all dealt with species that are relatively well known such as grizzly bears, whooping cranes, humpback whales and bald eagles. This has significance for this study, since we, in part, attempt to value a lesser known species, the least tern.

CVM has been under intense scrutiny as of late and has been the subject of debate among economists and others for the last decade. The CVM literature is extensive and although much progress has been made, CVM has been under attack for failing to come up with reliable and accurate measures of value (Diamond and Hausman, 1994, McFadden and Leonard, 1993, and Diamond et al., 1993 are some of the most recent critics). Stevens, et al., 1991, suggest that since wildlife benefits are difficult to quantify, CVM results are sensitive and values are likely to be volatile, benefit-cost analysis should not be used to make decisions. This study helps to alleviate some concern. We argue that a careful survey design can eliminate many of the biases that have caused the controversy.

Survey Design

The survey instrument is currently being pretested using focus groups and one-on-one practice interviews. The survey has been designed following many of the guidelines set by a 1993 panel convened by the National Oceanic and Atmospheric Administration (NOAA), as well as guidelines from Portney (1994), Mitchell and Carson (1989), Hanemann (1994), and Freeman (1993). The only deviation from these guidelines is the WTP question as discussed below. The survey instrument is a personal interview that consists of four key components.

1. ***A description of the watershed and the species to be valued:***

   An important factor in the effectiveness of a contingent valuation survey is that the survey respondent must have a clear and accurate idea of the specific good that is being valued. In the case of wildlife, this is often a difficult concept to convey, because there are countless ways of viewing the resource. The respondent could as a result be considering their willingness to pay for a good that is different from the one being asked about in the survey. If restoration of the West River improves habitat for the least tern, a survey question that asks about the value of the least tern will be ambiguous. Is it referring to the bird itself, reduced chance of extinction for the bird, increased probability of viewing a least tern during a visit to the West River, or the habitat it lives in?

   Related to this is an issue known as "part-whole bias" or the "embedding effect," in which respondents produce equal values of willingness to pay for two goods, one of which is a subcomponent of the other. The model of the effect is described as follows (Brown et al., 1995). A good of interest, known as a, is valued by one set of subjects. Then, a larger good, S, that includes is valued by another set of subjects. Since studies of this type have obtained results that a = S, the conclusion is that either S is not valued at all (which is unlikely), or that respondents value a as a component of S. In terms of wildlife, a small population of birds may be valued as a component of a larger population of birds. [Footnote 1] Another example, people express a desire to preserve wildlife because they value the habitat it lives in. Thus, the species is embedded within its habitat.

   We have addressed both of these problems by structuring our survey so that respondents are asked

about wildlife habitat. The resource being valued is a specific number of acres of wildlife habitat. Thus the detailed description of the watershed includes maps and photographs. We also have information on numbers of known breeding pairs currently in the watershed, probability of extinction (or some measure of vulnerability), pictures of the watershed, and a description of the proposed solution. The objective here is to provide a clear picture of the species being valued. [Footnote 2]

Information on the least tern is available from USFWS, Connecticut Department of Environmental Protection, and the World Wildlife Federation. Respondents will also be asked some introductory informational questions to get them thinking about the issues. Likely questions could be: How often do you visit the River (for the local subsample)? What activities do you participate in? Have you ever seen a least tern? Do you feel the continued existence of this species is very important? Somewhat important? Not important? Respondents will also be asked to characterize why they think continued existence is important. Respondents could be given a range of optional answers, that include use-values, bequest values or an intrinsic value. [Footnote 3] If the situation is properly framed any hypothetical bias and information bias will be drastically reduced, at least for the local sample. This will be ensured by the use of photographs and maps, a verbal description of the watershed and a detailed description of the proposed preservation program.

2. ***The Willingness to Pay question:***

The valuation question takes the form of a WTP question. A WTP response is an estimate of compensating surplus and it implies the respondent has no property right in the species being valued. A willingness to accept compensation for loss of a species question, on the other hand, would suggest that the respondent has a property right to the species. [Footnote 4] We do not feel this would be a relevant question.

WTP questions are in the form of an open-ended payment question. The WTP literature (in particular that on dichotomous choice) is extensive. The NOAA panel recommended the use of a dichotomous choice question in CV surveys so that the respondent is asked to make a familiar decision. An open-ended question, the panel argued, places the respondents in the unfamiliar situation of determining a value as opposed to voting or deciding whether or not to buy something. However, recent comparative studies of open-ended vs. dichotomous choice questions have revealed WTP bids that are much higher than those from open-ended questions (see for example, McFadden et al., 1993). The results from these more recent studies support the use of open-ended questions. This type of question should also eliminate any starting point bias that arises from a referendum type of payment question. The payment vehicle is in the form of a one-time private donation.

Respondents are being asked to value the restoration of a particular number of acres, rather than a number of birds (or a percentage of birds). Highlighted maps show representation of the areas.

Respondents are also reminded that any amount offered will reduce the amount of income available for the purchase of other goods and services. For example, the WTP question might be prefaced with a reminder to think about current income, the amount of money currently spent on other goods and services and other possible uses of income.

3. ***Socioeconomic questions:***

   Respondents are then asked questions to determine socioeconomic characteristics, environmental attitudes and behavior. These include characteristics such as age, education, income, affiliation with environmental organizations or bird watching groups, etc. This allows the construction of willingness to pay as a function of the various socioeconomic characteristics. Respondents are also asked about their attitudes toward animal preservation and about their general knowledge of the bird species.

4. ***Follow-up questions:***

   A series of follow-up questions are then asked to ensure that the respondent understood the scenario and the payment format and believed the information presented. Respondents are asked, for example, if they feel they will have to pay the amount specified if the policy is implemented or whether they believed the scenarios presented to be true. Respondents are also asked to give reasons for answers of "$0" to the WTP question. These questions also aid in the elimination of any protest bids. For example, respondents who respond with a "$0" to the willingness to pay question will be asked why they would not pay. Possible reasons will be outlined from which the respondent can choose. Some of these will be economic reasons (e.g. "cannot afford it"), others will be protest reasons (e.g. "taxes are already too high") , which, if chosen, can be eliminated.

   Statistical and econometric analysis of the survey data will determine whether or not this is indeed an improved survey design and whether or not any of the above hypotheses are to be rejected.

Discussion

An issue that is potentially problematic to our results is what has been called the "warm glow effect." In this situation, survey respondents state a price they would pay, but they may not be purchasing the environmental good being offered. Instead, they may be purchasing the price of moral satisfaction, of feeling good for donating to a worthy cause. Wildlife is particularly prone to this effect, because people value wildlife for several reasons which are not related to economic utility. Social, moral, ethical, legal, and even emotional considerations all contribute to a person's value of wildlife and desire to protect it. Such values are crucial, for they give support to protection and restoration of wildlife habitat such as the West River salt marsh. However, they can confound CVM surveys because these values do not easily translate into a willingness to pay figure, and in some cases, such as moral considerations, may actually create in the respondent hostility to the idea of placing any sort of price on the wildlife resource. Furthermore, people can value wildlife both for the ways in which they can use it (fishing, viewing) and

for its mere existence, even if they never will see it (such as people's concerns about species in the tropical rain forest they never will visit). Ideally, a CVM survey will be able to measure the sum total of both use and existence values. By focusing on the ecosystem of the restored salt marsh, we have hoped to capture the entire bundle of wildlife values for the West River.

A final issue to consider is uncertainty. Restoring the West River tidal marsh, for example, does not guarantee 100% chance of survival for the least tern. No species on the planet has a 0% chance of extinction. Acknowledging uncertainty in a CVM survey will obtain a more accurate measure of people's willingness to pay for wildlife resources; ignoring it will result in biased responses. We have incorporated the uncertainty factor into our survey by providing information about the vulnerability and probability of extinction of the least tern.

Results (Pending)

The survey described above is currently being pretested by focus groups at the Yale School of Forestry and Environmental Studies. Full data collection will be conducted during February and March. Compilation and analysis of survey data will be presented at Watershed '96. We expect to find significant quantifiable benefits to wildlife from restoring the salt marsh. Although our study has focused on one particular benefit of salt marsh restoration we will also present a categorization of the additional parties impacted including effects on property values, flood control and recreation.

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Footnotes

1. The Desvousges, et al., 1993, CV study of migratory waterfowl is commonly cited as an example of the severity of the embedding problem as respondents failed to distinguish between 2,000, 20,000 and 200,000 birds. However, the description of the situation was termed in percentages (e.g. "less than 1%") and no investigation was done to determine whether respondents perceived this to be a large or small difference.
2. For example, the respondent may be given the following information: "The Least Tern is a small, gull-like bird about nine inches long. It is the smallest of the terns. In the East, they nest from southern Maine to Mexico. They are known to inhabit both coastal and interior river systems."3 Stevens, et al., 1991, asked these types of questions in a survey on bald eagles in New England.
3. See Freeman, 1993 for a discussion of WTP and WTA with regard to property rights.

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Planning Ahead with Regional Storm Water Management Facilities in Florida

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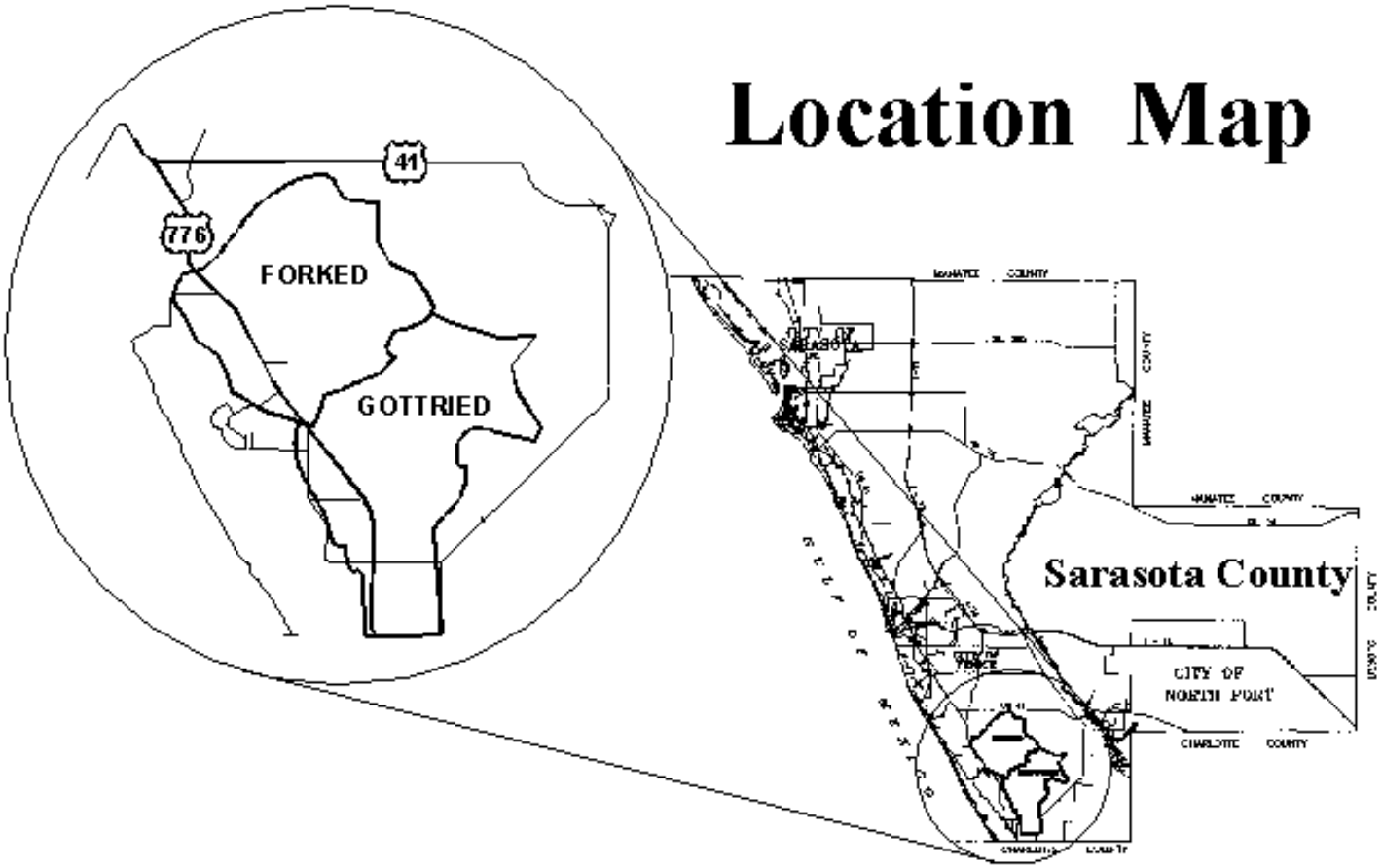
Introduction

Until recently, storm water management planning was based exclusively on flood control objectives. However, as the need to control the quality of storm water runoff has become more important, overall planning objectives now focus on the identification of solutions that balance those two often conflicting purposes. This study was created to identify both water quality and flooding problems, and to develop cost effective solutions, such as Regional Stormwater Management Facilities (RSMF's), in a basin that is facing increased development pressures. The study will also be used as a tool that will guide future development and, at the same time, protect the area's natural resources.

Description of the Study Area

The Gottfried Creek basin is a 7,300-acre basin, located in the southern portion of Sarasota County, Florida, and extending into the northern portion of Charlotte County (Figure 1). The creek discharges into Lemon Bay, which in 1987 was designated an Outstanding Florida Water (OFW). The OFW designation provides additional protection to waters recognized for their ecological and recreational importance.

Historically, the Gottfried Creek basin consisted of a series of contiguous wetlands and mesic hammocks that extended from the creek's headwaters to its outfall. In its original condition, the creek collected and conveyed water, nutrients and sediments from upland areas to discharge into wetlands and waterways. Channelization and extensive filling within the creek's flood plain and wetlands has reduced the capacity of the basin for natural water storage, thus increasing the potential for downstream flooding and erosion problems as well as water quality degradation. Based on the non-point pollution source assessment, the Gottfried Creek basin was categorized as threatened, which means that within five years some of the surface waters in the watershed will not support their designated use.



The extent of existing land uses in the basin was determined from land use/land cover maps based on the Florida Land Use And Cover Classification System (FLUCCS) and show 30 land use categories in the study area. The 30 land use categories were aggregated into six general categories. About 54 percent of the area is categorized as open land and 22 percent as wetlands. The remaining 24 percent is developed and consists mainly of low and medium density residential with pockets of commercial land uses. The future land use map represents build-out conditions. Over 70 percent of the basin area is expected to be developed with primarily low and medium density residential development.

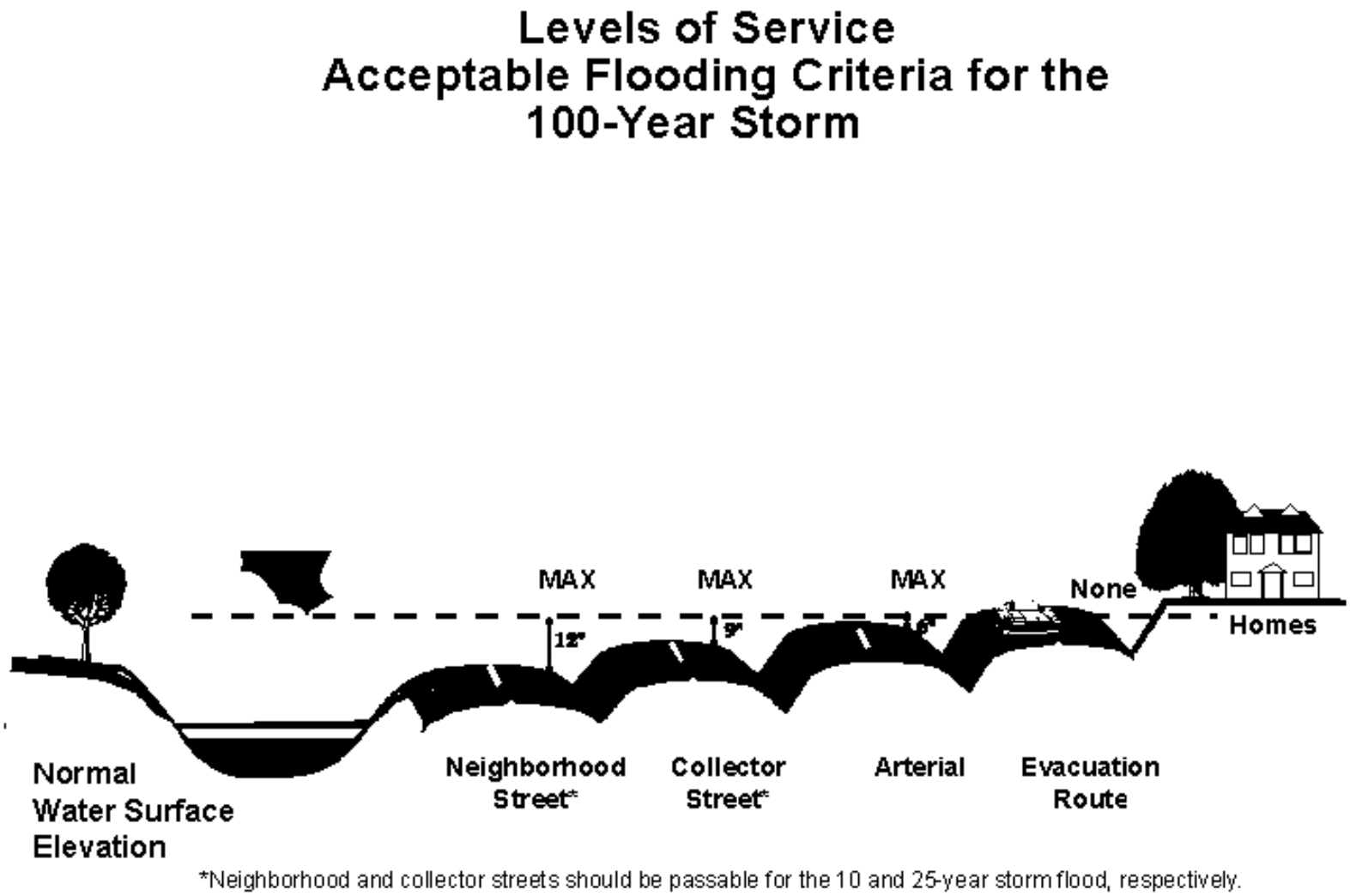
The objective of this study was to evaluate the extent by which flood protection and water quality Levels of Service (LOS) are being met in the basin and identify potential solutions and funding mechanisms to finance the proposed improvements.

Level of Service

A storm water management system that performs well is one that meets the flood protection and water quality LOS intended for it. LOS analysis for flood protection indicated that no emergency shelters, essential services, or employment/service centers would experience flooding during a 100-year storm event. However, numerous buildings, all residential, would be flooded during this flood event. In an apparent contradiction, practically all roads meet the established LOS. This is because houses in older developments are often built at elevations below those of the adjacent roads.

In terms of water quality, existing conditions in the basin are being threatened by development pressures. Erosion problems exist throughout the basin. In addition, available water quality data available indicated excessive concentrations of nutrients and coliform bacteria.

Flood Protection. The LOS criteria for flood protection are shown in Figure 2. The objective of this study was to insure that improvements are identified to meet the adopted LOS criteria under both existing and future land use conditions.



Water Quality. For this study, a methodology to determine water quality LOS deficiencies and objectives was developed herein based on both data analysis and Best Management Practices (BMP) coverages. The data analysis encompassed the evaluation of a non-point pollution source assessment as well as the calculation of the stream's water quality index (WQI). The WQI is based on the quality of water as measured by six water quality categories: water clarity, dissolved oxygen, oxygen demand, coliform bacteria, nutrients, and biological diversity. The WQI is the arithmetic average of the six water quality categories. The range of values for the WQI are as follows: 0 to less than 45 represents good quality, 45 to less than 60 represents fair quality, and 60 to 99 represents poor quality. The water quality LOS recommended for this basin is to achieve a minimum WQI of 53 throughout the length of the stream. The existing WQI in the stream ranged from 29 to 59.

Approach

The creek has four major conveyance systems, a main branch and three secondary branches, which contain a large number of culverts, bridges, and on-line and off-line detention facilities. The information on existing structures was stored as GIS files that combine graphical output and database capabilities.

For watershed modeling purposes, the basin was divided into three major subbasins and 31 smaller modeled subbasins with a median basin size of 115 acres. The subbasins were digitized in ArcCAD format and superimposed on the basin base map containing information such as land use and soil data.

The hydraulic analysis was conducted using the Extended Transport (EXTRAN) block of the U.S. Environmental Protection

Agency (EPA) Stormwater Management Model (SWMM). The input files were developed to conform with the input requirements for that model. Calibration and verification was conducted to ensure that the model was able to replicate natural conditions and to provide a degree of certainty to the predicted flood peak flows, volumes and elevations. Through the hydrologic analysis, it was determined that the SCS runoff curve number method with a shape factor of 150 and the Clark unit hydrograph method were the most appropriate for calibrating the hydrologic model.

Proposed Solutions

Various individual projects were identified in this study to improve flood control and water quality conditions within each problem area. The identification of those projects was based on the evaluation of alternatives in terms of costs, environmental impacts, regulatory and permitting issues, and community acceptance.

Proposed alternatives included varied levels of construction costs and complexity of design. For example, Alternative 1 ($240,000) for the Englewood Lateral addresses flood relief but does not address water quality LOS. Alternative 2 ($750,000) addresses flood relief and erosion control, which would result in reduction of the TSS concentrations in the main branch of the creek. Alternative 3 ($1,200,000) addresses flood relief and water quality LOS.

Due to the configuration of development in the basin, the main projects recommended for implementation were Regional Stormwater Management Facilities (RSMF's). RSMF's are storm water retention/detention ponds designed to provide attenuation and/or treatment of surface water discharge on a regional basis or for an entire basin. A RSMF may also be utilized for aquifer recharge, storage for water supply, wetland creation and mitigation banking, and for mitigation of flood plain impacts. Two RSMF's were recommended, one focusing on water quality control and the other on flood control. The proposed RSMF's would be designed with flow-through culverts such that they would be inundated during large storms, while existing hydroperiods in the upstream wetlands would be maintained.

The RSMF's construction would require an initial investment to be repaid by those benefitting from the facility's operation. Initial expenses will be financed by dedicated ad valorem taxes. The investment would be recovered in the future by one of various finance alternatives. Mitigation banking was also considered as a potential source of revenue. Future developments upstream of the RSMF would purchase the right to discharge a volume of runoff depending on specifics and individual characteristics. Benefits associated with the development of RSMF's include:

- Solutions to Regional Problems. Optimal results are achieved when drainage planning and design are integrated at the regional level. This approach provides local governments with adequate control of the physical components of the storm water management facility within a basin. RSMF's also allow for better coordination early in the planning stages.

- Solutions to Problems Associated with Volume and Peak Flow of Stormwater Runoff. Urbanization disrupts the natural equilibrium of streams. It tends to reduce the natural flood storage capabilities, increase both the peak rate and volume of runoff, and reduce the runoff travel time. By constructing RSMF's, adequate provisions can be made to mitigate the loss of storage capacity.

- Multipurpose Uses. In addition to solving typical problems associated with storm water runoff, RSMF's can provide drainage management strategies that meet a number of objectives, including water quality enhancement, groundwater recharge, wildlife habitat and wetland creation, control of erosion and sediment deposition, and creation of open space for recreational purposes.

- Enhancement of Natural Features and Drainageways. The design of urban storm water facilities generally require that a significant amount of land be devoted to the construction of storm water facilities. In many cases, this results in the elimination of natural features and the creation of unsightly structures designed to meet minimum regulatory requirements. Natural features can be planned, preserved and enhanced and made part of the design of RSMF's. Good designs that incorporate the use of natural features will maximize the economic and environmental benefits, particularly in combination with open space and recreational uses. These natural features include drainageways, depressions, wetlands, floodplains, groundwater recharge zones, and vegetation.

- Reduced Maintenance Costs. Rather than multiple associations and developments being responsible for the maintenance of several storm water facilities, it is simpler and more cost effective to establish scheduled maintenance of a single regional facility.

- Maximum Utilization of Developable Land. Through RSMFs, developers would be able to maximize the utilization of the proposed development for the purpose intended by minimizing the land normally set aside for the construction of storm water management facilities (an average of 20% of total land area is utilized for detention/retention ponds).

Conclusions

The construction of storm water management facilities to meet regulatory requirements has, in most cases, improved water quality and reduced flooding. However, These storm water management improvements have carried with them a steep price tag. A solution to the increased cost of construction of storm water management facilities is the development and construction of RSMF's. These RSMF's can be cost effective in areas experiencing development pressures such as the case with the Gottfried Creek basin and can offer long-term solutions at a low cost. In addition, most are designed and built as multi-use facilities where multiple benefits are achieved by serving a larger regional area.

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When The Dam Came Down-The Cold Creek Restoration Project

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History and Background of the Lake Tahoe Basin

Many mountain meadow ecosystems in the west ern United States have been hydrologically al- tered by the activities of European man. This paper will discuss the restoration of one such system, Cold Creek, a Sierra Nevada mountain meadow ecosystem located in the Lake Tahoe watershed.

Lake Tahoe, located on the California-Nevada border in the eastern Sierra Nevada mountains, is the tenth deepest lake in the world, with a mean depth of 1,027 feet and a maximum depth of 1,645 feet. The Lake surface is approximately 22 miles long and 12 miles wide and holds enough water to cover California to a depth of 14.5 inches. The characteristic which sets Lake Tahoe apart from most water bodies is its unique clarity. This clarity was documented in the 1960's with Secchi Disc readings of over 120 feet. The aesthetics of these pristine waters along with unique ecological qualities have resulted in the federal designation of Lake Tahoe as an "Outstanding National Resource Water".

Development of commercial and residential structures and road systems has resulted in disruption of the watershed. Loss of vegetative cover, construction of extensive impervious coverage, channelization of streams, and filling of wetlands, have generated exaggerated peaks and valleys in the hydrologic cycle and accelerated erosion rates. These landscape alterations have increased the flow of suspended sediments to the Lake with their associated load of phosphorous, nitrogen, iron, and other nutrients. The results of these impacts are established in long term studies which have shown a tripling of phytoplankton productivity since 1968, resulting in a reduction of over 40 feet in Secchi Disc measurements.

Background of Project Site

Cold Creek is a subwatershed to Trout Creek, one of 63 streams that transport surface flows to Lake Tahoe. The majority of the Cold Creek watershed is composed of steep, moderately forested, granitic soils with mountains peaks over 10,000 feet in elevation. The lower 5% of the watershed is composed of alluvium soils, with rolling hills and a gently sloping meadow adjacent to the last mile of stream reach. The meadow is well vegetated with rushes, sedges, grasses, forbs, deciduous trees and shrubs, and scattered lodge pole pine stands. The vegetation is supported by soils composed of a six inch peat layer over a sandy loam.

The Cold Creek watershed reflects the landscape evolution that has taken place throughout the Basin. The steep upper slopes have recovered from the logging at the turn of the century, while the gentler topography of the lower watershed has had 50% of its surfaced severely altered by construction of subdivisions, schools, highways, and an earthen dam.

The earthen dam, 400 feet long and 10 feet high, with an associated 1,500 foot long dike and 3,000 foot long diversion channel, was constructed by a local rancher at the terminus of this watershed, during the 1950's, to intercept and retain surface flows for agricultural purposes. The structure spanned the entire width of the meadow, inundating the original channel. Excess flows by-passed around the dam in a constructed earthen conveyance ditch along the periphery of the meadow. The new lake formed as a result of these structures was called Lake Christopher.

Subsequently the meadow, Lake Christopher, and adjacent uplands were sold to a developer for subdivision. Upon completion of the subdivision the developer deeded Lake Christopher and the adjacent meadow to the City of South Lake Tahoe. The City soon learned that they had a faulty dam and were required by the State of California to breech the condemned structure.

A city project in 1989 had targeted breaching the condemned dam and improving waterfowl habitat. The project was successful in establishing two 0.75 acre shallow ponds for loafing and feeding activities for waterfowl. Also, construction of a secondary feeder channel which conveyed water to the ponds and breached the dam was completed. The remainder of the dam was left intact as was the by-pass channel.

Project Initiation

The dam and a deeply entrenched linear by-pass channel had eliminated the filtering function of the soils and vegetation of the adjacent 40 acre meadow system. This loss, combined with the high runoff peaks from adjacent subdivisions, was a recognized nonpoint source problem affecting the water clarity of Lake Tahoe.

In 1992, the City of South Lake Tahoe, the owner of the site, requested funding from the California Tahoe Conservancy (CTC) to remove the existing dam and associated earth works and construct a new

channel. Funding was granted and the City sought out the assistance of the Tahoe Resource Conservation District (TRCD) and the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, for design and construction oversight.

NRCS was given the lead in the design process and initiated the development of alternatives through close coordination with the City, CTC, Tahoe Regional Planning Agency, CA. Fish and Game and the CA. Water Quality Control Board-Lahontan Region. The initial planning meetings with this group identified areas of concern which were; emulating original channel configuration, low impact construction techniques, and maximizing salvage of native vegetation on site.

Community meetings were also held at a local school adjacent to the project site. These surfaced several areas of concern. Residents adjacent to the meadow questioned the ability of the designers to construct a channel that would be stable and not require extensive future maintenance. There was also a concern for the well being of a local beaver population. Those individuals whose properties were adjoining the man made conveyance ditch, were upset over losing this amenity (water frontage), if it was filled and a new channel constructed in the meadow.

NRCS provided responses to these concerns over a series of 3 meeting/workshops. The need for restoring the role and function of wetlands in protecting the water quality of Lake Tahoe was explained in the context of the existing condition of the Lake Christopher area. Using local stable stream reaches as models for development of the new channel was supported by the group as a logical means to potentially obtain long term stability. A committee of citizens and agency representatives was formed to develop a beaver management plan. This plan addressed the need to temporarily disperse beaver from the project site in order to dewater the meadow for construction. The committee chose to remove beaver dams with hand labor during the summer prior to construction. This allowed time for the meadow to dry out and the beaver to relocate before winter.

Project Development

The intent of the Cold Creek Restoration Project was to reestablish the historical functions of this mountain meadow/stream ecosystem, through the removal of the man made structures, implementation of a geomorphic channel design, and restoration of the associated hydrophytic vegetation.

Design Approach

Designing a dynamically stable channel which would restore the hydrologic characteristics of this alpine meadow as part of a self sustaining ecosystem, presented an interesting challenge to the NRCS staff. Historically NRCS provided engineering designs which were static and carried specific life expectancies. The approach needed to meet these new design criteria required a willingness on the part of NRCS design team engineers, at both the local field office and California state office, to reinvent their traditional design process.

This was done by first accepting the fact that self sustaining ecosystems fluctuate in form and function over time. Using this premise, existing examples of healthy stream/meadow ecosystems with similar hydrology, topography and soils would provide models to work from. Combining this geomorphologic approach with traditional hydraulic analysis, would provide data that both traditional engineers and restoration specialists could work with together.

Using this new planning approach, it became apparent that both the sponsor of the project (the City), the funding entity (CTC), and the regulatory agencies had to be willing to accept the concept of a dynamically stable channel. Again, rather than NRCS assuring a specific project life, it was disclosed that the channel would in fact fluctuate over time. These fluctuations would be in concert with the soils, flora, and fauna, of the meadow ecosystem in such a way that it would not only be non- degradating, but produce beneficial results both on and off site. This approach was adopted by the NRCS on this project and accepted by all participants in this effort.

Channel Design Analysis

Hydrology

Discharge was determined from a U.S. Geological Survey (USGS) stream gauge station located 3,500 feet downstream from the juncture of Trout Creek and Cold Creek, which has recorded peak daily discharges since October 1960. This data was extrapolated to the Cold Creek drainage by a ratio of the associated land areas for the two watersheds. This produced a 35:65 theoretical ratio of discharge, Cold Cr. to Trout Cr.. Flow data collected with a pygmy flow meter in Trout and Cold Creek, substantiated this ratio of flows. Using the 35:65 ratio, a predicted 2 year recurrence interval discharge of 50 cfs. was determined. This data would be used to design channel capacity to facilitate over bank flows during 2 year (or greater) flow events.

Channel Geometry and Hydraulics

Geomorphic design requires factoring the interaction of: stream velocity and discharge, valley slope, land form, soil properties, rooting depth and density of vegetation, sediment size and load, channel slope, width, depth, energy grade line and flow resistance, to design a dynamically stable channel.

These factors were addressed through the use of the analytical programs; NRCS "Hydra" program for open channel hydraulics, NRCS "Reaches" for geomorphic geometry, US Army Corps of Engineers "HEC 6-Scour and Deposition in Rivers and Channels", and "Agricultural Nonpoint Source Model " (AGNPS) for sediment yield from the watershed.

A stream classification system that identifies various geomorphic stable stream types based on the previously identified factors was developed by Dave Rosgen of Wildland Hydrology, Pagosa Springs, Colorado. This classification system was used to determine the most appropriate geomorphologic stream model for this project. This was an "E" type channel in Rosgen's classification system. Mr. Rosgen also

provided consultation in the form of the " Stream Restoration Design Recommendations, Cold Creek, Tahoe Basin, California", 12/3/92, document, along with a site visit during initial field fitting of the design.

In order to determine an appropriate stream type and geometry, on the ground measurements were taken on stable reaches of Trout Creek. This data was scaled back to Cold Creek using the ratio of the bankfull discharges. The NRCS also measured channel meander geometry of the original Cold Creek channel from a 1940 aerial photo. This process produced a channel model with a sinuosity of 2.0, channel gradient of .0025, a meander length of 115 feet , radius of curvature of 25 feet, channel width of 5.5 feet, and channel depth of 2 feet.

Project Implementation

Contractor Training

The construction process called for minimizing impacts while implementing new and unique structural and vegetative applications. These needs were initially addressed by requiring all contract bidders to participate in a site tour in order to be eligible to bid. At the site tour the sensitivity of the site was emphasized and the unique applications were discussed. The successful bidder was then required to have their machine operators and project managers attend a half day workshop on site . NRCS staff and CTC consultants from Interfluve of Hood River, OR. used clay models to explain placement of boulders and root wad/stumps in revetment applications. Additional information was given on machine techniques for vegetation salvage and minimal impact operation. The benefits of this training were noted in quality work throughout the project. Quality control was also assured by the continual presence of two contract inspectors during construction.

Haul and Access Systems

Site access for dam removal, channel construction and fill placement was addressed through the use of two temporary road systems. Main haul roads were constructed by first placing geotextile fabric on the meadow surface and then covering it with coarse material excavated from the dam and dike. Short term access routes associated with new channel construction and revegetation were protected through the use of portable military landing mats. All road materials were removed at the end of construction activities. Vegetative recovery was 100% along these travel routes after one full growing season.

Revegetation

Salvage and transplant of native sod and willows and seeding of grasses and forbs with mulch were the primary revegetation techniques. Thirty-two hundred square yards of sod were mowed to a 3-4 inch height then excavated in 4 foot by 8 foot by 8 inch sections from the path of the new channel using sod knives and a rubber tired, front end bucket loader. Two hundred and seventy willows were trimmed to 8 inches of top growth then excavated with a rubber tired backhoe. Placement was done within 30 minutes

of excavation for both willows and sod. Two seeding mixes were applied to address the hydrologic conditions of the soils. A "wet meadow mix " for 61,000 sq. ft. of meadow and a "dry meadow mix" for 127,000 sq. ft. uplands. Seeded areas were mulched with straw and tackifier. Salvaged top soil from the dam and dike excavation provided an additional source of plant materials with its inherent mixture of rhizomes, roots, corms and seeds. This material was disced into the surface of the diversion channel fill. All revegetated areas were sprinkler irrigated.

Channel Construction

Three stream "types" were selected for construction. First, the majority of the channel (4,000+ ft.) was an "E" type, which is highly sinuous, low gradient with a low width to depth ratio. A second and third channel types, "B" and "C", were needed for grade transition, due to steeper valley slopes both at the upper end of the project where a road culvert existed and through the old dam foot print. The "B" type is a riffle dominated, pool/riffle, moderately entrenched channel. The "C" type is a slightly entrenched pool/riffle, meandering channel.

Channel location was delineated by the sod removal which occurred prior to channel excavation for all channel types. The "E" type channel was constructed with a tracked excavator, which straddled the channel as it progressed. The channel cross section was a 1.5-2 foot deep, 5-6 foot wide rectangular form, which allowed the machine operator to progress at a smooth pace. Constant thalweg grade alignment and channel dimension checks were provided by the construction inspector. This "E" type channel is dependent on a strong healthy vegetative cover with adequate root depth and density, to maintain bank integrity. Fortunately the majority of the channel path already supported a healthy stand of rushes, sedges, grasses and forbs. However, deeper rooting plants such as willows were lacking in some areas of the channel. In these areas, salvaged willow root wads were transplanted on the outside of the meander curves to provide their deep rooting stability.

The "B" type channel at the dam foot print and the upper end of the project required the installation of rock vortex weirs to provide grade control, and placement of salvaged sod to establish appropriate bank heights.

The "C" type channel was used to transition the "B" type into the "E" type at both the upper end of the project and at the dam foot print. The "C" type included rock vortex weirs for grade control, biomechanical bank revetment, salvaged sod and willows, and placed coarse bed load material.

The biomechanical bank revetment consisted of 12-18 inch diameter footer logs placed parallel to stream flow and at an elevation excavated to be flush with the thalweg. A 7 foot long stump of similar diameter is then placed diagonally on the footer log, with the face of the roots oriented from 45 degrees to parallel with the stream flow and the bole extended into the bank. Then, 18-24 inch diameter rocks were installed between the log structures to anchor them in place. These structures are backfilled with soil and sod and willows are planted. This type of revetment provides structural stability, a natural looking appearance, and excellent fish habitat.

A sod lined, 10 cfs feeder channel and head gate structure was also constructed to provide flows to the existing waterfowl ponds.

Results

The project was completed in October of 1994. The following winter of 1995 brought 300% of normal precipitation, including a major rain on snow event in March. The flows associated with this event and subsequent spring snow melt in June and July, produced out of bank flows for over two months.

The project was highly successful in its primary goal of reestablishing the historical hydrologic functions of this mountain meadow/stream ecosystem. The transplanted vegetation withstood the inundating surface flows and up to 2 feet of sediments which were trapped on the flood plain. Runoff from adjacent subdivisions which formerly discharged directly into surface water, was now filtered through 300 feet of meadow vegetation before reaching Cold Creek. Some deposition of bed load sands did occur in the Cold Creek channel, but the majority of this material cleared as the flows receded. The few areas of the channel that did not flush were cleaned out by City hand crews.

This project was monitored during the summer of 1995 for discharge; water temperature, vegetative success, and channel morphology. This information has been compiled in a report for the project sponsor and funding agency. The data obtained from both this monitoring effort along with experience of designing and constructing this project, will provide a strong base for future stream restoration efforts within the Tahoe Basin and throughout the Sierras.

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Erosion and Sediment Control: Preventing Additional Disasters after the Southern California Fires

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Introduction

Wildfires are a common occurrence in Southern California and much of the State's biologic and geologic character is a direct result of a cycle of fire, flood, and regeneration of plant communities, many of which have adapted to this disturbance. However, while the impact of fires might be considered a natural phenomenon in wild lands and left largely unattended, where human population and resources are affected by the fire cycle, mitigation activities designed to reduce the potential for flooding and mud flows must be included as part of that cycle.

In the fall of 1993, 20 separate fires burned over 186,000 acres of Southern California, extending from northern Los Angeles County to southern San Diego County and the Mexican border. Nearly 1,200 homes were destroyed and four people lost their lives. Unlike the 1991 East Bay Firestorm in Oakland, California where 3,100 structures were destroyed in an 1,800 acre densely populated urban area, the majority of acreage on which the 1993 fires occurred was in wild lands, or away from urban centers. However, at the urban interface where wild lands and development meet, the hazard from post-fire flooding, erosion, sedimentation, and mud flows can directly impact human populations. In the crucible that constitutes post-fire disaster planning and implementation, it is the potential occurrence of this

second disaster which challenges federal, state, and local government entities to allocate human and financial resources and focus them into immediate and effective actions.

This article presents information on the post-fire hazard assessment and mitigation planning conducted by Woodward-Clyde Consultants (WCC) for the California Office of Emergency Services (OES) and its implementation in the communities of Malibu, Thousand Oaks, Laguna Beach, and Orange County.

The Post-Fire Hazard

Considerable information is available on post-fire sediment production rates and debris flows in California, particularly in Southern California, including studies by Wells, the Handbook of Applied Hydrology by Ven Te Chow, and the Los Angeles County Hydrology Manual. These studies show that fire accelerates erosion rates in California chaparral to such an extent that it must be considered the major factor which drives sediment production on these lands. The surface processes of dry ravel and rill network formation are major contributors to this accelerated erosion, and debris flows are a common occurrence. These flows move most of the sediment produced after a fire, and can occur following very little rainfall.

The incidence of fire temporarily reduces the beneficial effects that plants provide in reducing soil erosion. Plants provide cover that intercepts and reduces rainfall impact, the primary mechanism for soil erosion. Vegetation also increases the infiltration of water into the soil, reduces runoff velocities, filters out sediment, and provides plant roots to hold the soil together. Without vegetation and its benefits, sediment production and runoff in fire-affected areas and more important, its delivery down slope increases.

Burned watersheds erode in different ways, depending on soil type, climate, vegetation, burrowing and grazing animals, topography, and human activity. Dry creep, or dry ravel, is the downhill movement of soil and debris during dry periods, and is caused by gravitational forces. Where fire burns the vegetative cover, the mechanical resistance to gravitational forces decreases, and the soils become more susceptible to this type of erosion. Dry ravel is a major erosional force in post-fire conditions. Soil and debris accumulates at the base of slopes and remains stored until mobilized by intense runoff. This is known as channel loading. Intense runoff often occurs after a fire and can be the result of the development of soil hydrophobicity.

Hydrophobic, or water-repellent soils can develop from substances in the soil which are vaporized during the burning of surface litter, particularly on sandy soils. Hydrophobic soils are created as the fire breaks down organic matter and chemicals in the soils, releasing a gas which coats soil particles and reduces water penetration. This condition reduces water infiltration rates and moisture storage capacity resulting in increased runoff and erosion rates. After fire, soils are no longer protected by vegetative cover from turbulent air. Wind is an erosive force in these conditions, blowing slopes clean of loose soil particles. The windblown soils are usually deposited down slope and in stream channels for later movement during storms.

The development of rill networks and gully erosion increases post-fire loss during the rainy season when soils are wet or saturated. Infiltration rates are decreased on bare slopes, and therefore, runoff, or overland flow increases and the sediment carrying capacity increases. The result of this type of erosion is the movement of sediment and debris into stream channels, causing clogged drainage ways, mud flows, and debris flows. Since the rate of runoff is higher and the sediment and debris load is higher, the potential for flooding is also increased. Soil slippage can occur during heavy rains when the amount of water entering the soil layer exceeds the capacity of the parent rock to transport water. This leads to supersaturated soils, and soon the stress on the soil exceeds its strength, resulting in sloughs and slumps. After fires, even moderately heavy rainfall can supersaturate soils denuded of vegetation.

There is generally a higher flooding risk as a result of a fire. This increased risk may arise from increased watershed runoff due to changes in the surficial soil and vegetation characteristics as previously described; diversion and/or overflow of conveyance facilities due to increased sediment loads from the barren watersheds, and the possibility of additional flooding from ineffective sediment basins. Post-fire conditions can also result in reduced-stability landslides and other geologic hazards. Examples include: erosion of supporting rocks or soil at the toe of a pre-existing slump or landslide; damage to a landslide stabilization measure (such as a drainage or dewatering system); and damage to earth retaining structures or other slope stabilization measures.

Issues and Concerns

Erosion, flooding mud flows, and debris flows following fires are considered by some geologists and geomorphologists as naturally occurring phenomena that don't require man's intervention. Government officials and the people in their jurisdictions who are directly impacted from post-fire hazards tend to think of them as anything but natural, and demand effective and immediate mitigation measures. Three of the questions that arise after a fire are: "Should we do anything at all?," "What should we do?," and "How much is enough?." Although the technical answers associated with appropriate response following fires may be years away from resolution, i.e., whether to mitigate, revegetate, or evacuate, the realities of the hazards and impacts on human populations require some type of action.

It might be instructional to consider the agricultural concept of "T," or tolerable soil loss. Tolerable soil loss is considered to be that amount of soil which can be lost on an annual basis without affecting a site's productivity, or its ability to support a multitude of uses. A certain amount of erosion might be permissible in an agricultural setting, with losses offset by adjusting management inputs, and erosion of outlying wild land areas is offset by natural soil formation over time. But, when the effects of accelerated erosion from fires affect people's lives, property, and community infrastructure, there is no tolerable soil loss. If 99 percent reduction in erosion still results in 1 percent of the sediment filling up someone's living room to the ceiling, then there is no soil loss which is tolerable in the urban environment.

In the case of the Southern California, logic dictated that remediation could not be pursued on all of the areas affected by the fires. Not only were the costs prohibitive, but natural regeneration in the extensive

area of affected wild lands occurs at a rate much more rapid than man's effort to augment it. Limited economic and human resources were then directed, as they should have been, towards the affected communities of Laguna Beach, Malibu, Altadena, Thousand Oaks, and parts of Orange County.

Hazard Assessment

The planning and implementation of post-fire hazard mitigation measures require a documentable process wherein the effort is phased to allow the highest hazard areas to be identified and addressed first, followed by the next most urgent hazard areas. During and immediately following the fires, available information was gathered and reviewed for identification of potential hazards. This information included storm drain maps, topographic maps, geologic maps, hydrologic information, and aerial photographs. Both aerial and ground site reconnaissances were performed with two-person field teams to assess the damage and gather information on the potential hazards caused by the fire, including mud flows, debris flows, and high sediment loads; flooding; rockfalls; retaining structure damage; and landslides.

Based on the gathered information, the potential for post-fire hazards was evaluated and tabulated for various sites within the burned areas, Next, the impacts of those potential hazards were evaluated. Impacts of the post-fire hazards included public health and safety; public and private property damage; damage to infrastructure (such as the storm drain system); transportation route damage (such as key artery loss); or damage to receiving waters. Based on an assessment of the likelihood of the hazard together with the severity of its impact, an overall judgment was made as to which sites, if any, should have the highest priority for mitigation. This evaluation was a particularly valuable tool for allocating resources. An example of a hazard assessment matrix is presented in Table 1.

Table 1. Assessment of burn area hazards

	Hazard					**Impacts**					**Overall Rating**
Fire/site	**L**	**M**	**F**	**R**	**S**	**H**	**P**	**I**	**T**	**W**	
Fire 1											
Site 1	L	H	H	M	N	H	H	M	H	L	H
Site 2	M	H	H	H	M	H	H	M	L	L	H
Site 3	L	M	H	L	M	L	H	L	M	L	M

Legend: H=High M=Medium L=Low N=None

L=landslides; M=mudflows/debris flows/high sediment loads; F=flooding; R=rockfalls; S=retaining structure damage; H=public health and safety; P=public and private property damage; I=damage to infrastructure; T=transportation route damage (artery loss); W=damage to receiving waters.

In both the Oakland and Southern California Fires, this technique was used, and resulted in mitigation efforts being focused on those hazards that would have a high impact on public health and safety, public and private property damage, infrastructure damage, transportation route damage, and damage to

receiving waters. In all cases, these hazards occurred at the urban interface areas. Where there were potential hazards with a medium or high likelihood of occurring, but the potential impacts were low, then no mitigation of the hazards was recommended or implemented. Typically, this occurred in the more open, undeveloped areas.

Development of Plans

The first step in mitigating the identified high priority post-fire hazards was to develop Early Action Plans that provided for immediate sediment control to reduce the impact of flooding and mudflows on developed areas. Early action measures should be identified to implement immediately if rains are imminent. Both the Oakland and Southern California fires occurred in late October at the start of the rainy season, and in both cases Early Action Plans were prepared and being implemented within a week of the fires being put out. These early action measures were intended to provide as much preliminary protection as is practical in critical areas while the more comprehensive Phase I Mitigation Plans were being prepared.

Early action measures were usually those measures that could be implemented using available work force crews (manual labor primarily), and focused on sediment and debris control. They included removal of debris from drainages; cleaning out storm drains; protection of storm drain inlets; construction of temporary velocity reduction measures, check dams, and sediment traps; and construction of sand bag diversions.

The project authority had at least four sources of labor for immediate action and response: the California Conservation Corps (CCC), work release program crews, local maintenance crews, and volunteer organizations. The project authority needed to develop a program of orientation, training, and oversight. This resulted in the timely and safe implementation of early action measures. These early action measures typically were not intended to eliminate, only reduce, damage from rainfall-induced flooding and mud, rock, and debris flows. It was recognized that the first significant rainfall after the fire would result in unexpected problems with increased flooding and mud and debris flows, so trained personnel were in the field to help citizens and assess needed repairs and improvements in the early action measures.

The next step in the process was to develop Phase I Hazard Mitigation Plans, which are comprehensive plans for a given area designed to address the short-term mitigation of geologic, erosion, and flood hazards caused by or exacerbated by the fire. These short-term mitigation measures were designed to address immediate threats to public health and safety, including ash, debris, sediment, and flood damage to public and private property. The measures provided for both erosion and sediment control. The Phase I Plans included provisions for operating and maintaining the installed systems throughout the rainy season.

The essential steps taken in developing the mitigation plans were: (1) Identify the Issues and Concerns; (2) Develop Goals and Objectives; (3) Perform Post-Fire Hazard Evaluation; (4) Develop Best

Management Practice (BMP) Selection Criteria; (5) Nominate and Evaluate Alternatives; (6) Screen and Select Alternatives; (7) Design the Hazard Mitigation Plan; (8) Implement the Plan; and (9) Operations and Maintenance. Since the fires occurred during the rainy season, Steps 1 through 8 had to be implemented as quickly as possible. Typically, this took a week to ten days. Based on the knowledge and local experience of the project authority's hazard mitigation team, some analyses and screening detail could be reduced. For example, clearly, areas where flooding and other geologic problems were present before the fire were likely to be worsened. However, a rational, well-documented decision process was essential to help with local, state and federal disaster funding.

The third step in the plan development process was to prepare Phase II Hazard Mitigation Plans that were designed to address the longer term mitigation of fire impacts relative to geologic, erosion, and flood hazards. These were optional plans, but where deemed necessary, included the next level priority areas after the Phase I Plans were implemented, site disturbance from debris removal and the reconstruction process, and/or semi-permanent drainage design modifications necessitated by changed post-burn conditions.

Mitigation Measures

The wide range of conditions encountered following a fire in an urban or urban-wild land interface area require a variety of Best Practical and Available Technology (BPAT) solutions designed to address hazards under site-specific circumstances. These solutions are commonly referred to as Best Management Practices (BMPs). The BMPs selected for implementation in potential hazard areas were evaluated utilizing the following selection criteria: effectiveness; implementation cost; long-term (maintenance) cost; environmental impacts; regulatory acceptability; public acceptability; risk/liability; aesthetics; suitability for site; feasibility; and durability or longevity.

No numerical equation presently exists whereby an emergency mitigation planner can establish the most appropriate solution to a post-fire problem. In almost all cases, successful erosion and sediment control involves a variety of techniques and materials which are pulled together to form a complementary and composite system of BMPs. Above all, post-fire hazard mitigation must been done quickly... and be effective.

Twenty BMPs were selected for implementation in the urban-interface areas of Laguna Beach, Orange County, Malibu and Thousand Oaks. Not all of the BMPs were used on sites, and in some areas, specific practices were relied on more than others. With all revegetation BMPs, the seed mixtures were specified by the Soil Conservation Service (SCS) as part of their technical assistance provided to affected communities through the Emergency Watershed Program. These seed mixtures were composed primarily of native plant materials selected to complement indigenous plant re-establishment. SCS field engineers also worked with contractors hired by the communities, assisting in the coordination of work activities and inspecting applications.

It is important to note that neither re-establishment of native plant materials (from root or seed which

survived the fire) nor introduced vegetation (through hydraulic or broadcast seeding) appears to provide enough soil protection in the first year following a fire to prevent erosion. For this reason, a two-pronged strategy was employed which included: first, sediment control, detention and diversion; and second, temporary cover practices to hold the soil in place until vegetation is established.

The sediment control practices were used in the immediate response to reduce the down-slope impact of sediment until soil stabilization measures could be implemented. These aggressive, source control practices provided an immediate, temporary cover that reduced the erodibility of soils until permanent, soil-stabilizing vegetation was re-established. Although all of these revegetation practices were used on the fire-affected areas to some degree, primary emphasis was placed on the use of hydraulic practices due to cost, timeliness, topographic, environmental compatibility, and safety concerns.

Conclusions

It should be recognized that of the 186,000 acres affected by the fires of 1993, less than 1 percent of the area (<1,800 acres) received the comprehensive erosion and sediment control treatments described in this paper. These were the urban and urban-interface areas of highest priority identified in the Hazard Assessment provided to the California Office of Emergency Services. Orange County, Laguna Beach, Thousand Oaks, and the Big Rock area of Malibu received individual plans prepared for each community by Woodward-Clyde, and to a large degree, when implemented, these plans were effective in mitigating the erosion and sedimentation impacts from winter storms.

Much needs to be learned about post-fire emergency erosion and sediment control in the urban interface and not just from a technical standpoint about which practices should be used to mitigate impacts. We should accept the fact that the cycle of wildfires and the resulting erosion and sedimentation is a natural phenomena in Southern California and other western states as well. But to the people who are affected by these processes, those living at the urban-wildland interface, questions on whether or not to use any mitigation practices at all are moot: Do-nothing alternatives are not politically, technically, economically, or socially acceptable. People and their activities are as much a part of the post-fire environment as are native plants and animals, and any approach that does not incorporate human resources and values as part of a mitigation strategy fails to appreciate the practical interface between humans and their environment.

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Watershed Planning Study for Urban and Rural Pollution Sources

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Typically, when problems with water quality occur, the focus is quickly directed to local permitted dischargers with the requirement that they improve their effluent. However, the causes for poor water quality cannot always be ascribed to the permitted dischargers, and misdirected "clean-up" initiatives can be a significant waste of both public and private time and money.

The watershed management approach is a fair and cost-effective method that communities nationwide are using to efficiently and effectively improve water quality. Point and nonpoint pollutant sources are inventoried, and the most cost-effective improvement plan is developed based on the relevant pollutant sources. A range of hydrologic, land use, and water quality data is gathered from available sources or collected to determine the relative pollutant loadings.

A case in point is a creek within the service area of the Water Works and Sanitary Sewer Board (Board) of the City of Montgomery, Alabama. The Board faced spending more than $50 million for capital improvements to the "separate" sanitary sewer system for the next several years to eliminate sanitary

sewer overflows (SSOs) that were occurring during wet weather events. The SSOs allegedly were affecting creek water quality. Instead of immediately designing sewer improvements, the Board requested and was granted permission by the Alabama Department of Environmental Management (ADEM) to conduct a water quality study to assess the effects of its overflows on the receiving creek's water quality.

The study showed that the pollutant loading from the SSOs was only a small percentage of the total pollutant loading to the creek. Therefore, the Board requested that a watershed management approach be used to help improve the creek's water quality. This initial assessment has led to a cooperative watershed management study endorsed by key "stakeholders" from regulatory and management agencies, as well as by contributors of pollutants. The potential benefits of this approach are water quality improvements in a shorter time period for less capital expenditure.

Catoma Creek Watershed Characteristics

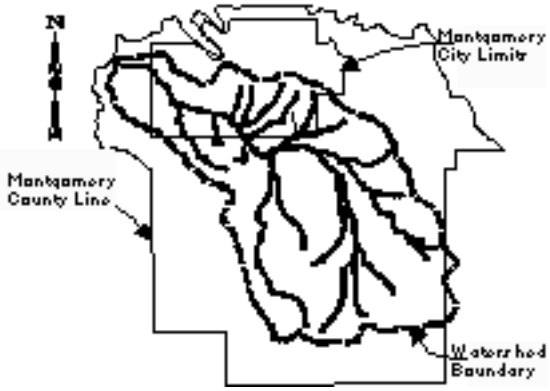

Figure 1. Catoma Creek Watershed

Catoma Creek has a watershed of approximately 347 square miles, with the majority of the watershed located within Montgomery County (Figure 1). The creek drainage area is predominantly rural, but includes urban/suburban drainage from the southern half of the City of Montgomery before this drainage enters the Alabama River. Table 1 provides a general breakdown of land use within the Catoma Creek watershed.

There are only a couple hundred acres of cotton, sorghum, and corn. Most of the agricultural activities consist of small animal operations with several dairy farms and cattle feed lots in the watershed. There are approximately 63,000 cattle within the watershed, in addition to an estimated 100,000 dogs and cats.

Catoma Creek is formed by several smaller creeks that drain rural areas as well as portions of the City. The urban portion of the creek is characterized by a vast floodplain that encompasses the nearly 30

Table 1. Catoma Creek Basin Land Use.

Land Use Category	Cover (acres)	% Cover
Forest	81,000	36.5
Open Area (Primarily Floodplain)	65,070	29.3
Pasture	35,980	16.2
Low-Density Res.	15,990	7.2
Rural Residential	8,880	4.0

percent of the watershed that is classified as Open Area in Table 1. Although substantial portions of the Catoma Creek watershed have been developed, the major portion of the stream habitat has not been modified, primarily as a result of the protection provided for the extensive floodplain.

Commercial	6,220	2.8
High-Density Res.	5,110	2.3
Industrial	3,780	1.7

The entire Catoma Creek watershed has a use classification for Fish and Wildlife in the Alabama Water Quality Standards. This classification "recognizes that the waters may be used for incidental water contact and recreation during June through September." Although this means that the stream has a water quality standard for fecal coliform related to swimming use, there is limited access to the creek.

Pollution Sources

Three major sources are recognized in the watershed as having the potential to introduce pollutants into the creek: the Catoma Water Pollution Control Facilities (WPCF) collection system, storm water runoff from the City of Montgomery and adjacent developing areas, and farming operations.

Catoma WPCF

The Catoma WPCF includes a treatment plant at the mouth of Catoma Creek that discharges outside the watershed, and a collection system that has overflows up in the watershed. The collection system serves southern Montgomery and contains about 479 miles of sewer pipe.

Some portions of the collection system have infiltration/inflow (I/I) problems, which probably result from the installation practices used on older sections of the collection system. In addition, the flat slopes in some sections limit hydraulic capacity. The Board has conducted source detection studies to help identify excessive I/I areas, and currently is expanding the Catoma WPCF's treatment capacity in addition to aggressively rehabilitating the collection system.

Storm Water Runoff

The City of Montgomery has been required to submit a National Pollutant Discharge Elimination System (NPDES) permit application for storm water discharges as a municipality with a population in the range of 100,000 to 250,000. This NPDES permit application is still under review by ADEM. In addition, storm water discharges from industrial activities including construction activities are required to be covered under appropriate general NPDES permits specific to the activity.

Farming Operations

ADEM has a nonpoint source program that addresses agricultural activities. Currently, farming

operations within the Catoma Creek watershed are not regulated, and there has been no specific targeting of voluntary programs in the watershed.

Watershed Management Plan

The Board is active in developing a comprehensive watershed management planning effort. This project focuses on further definition of pollutant contribution from specific sources within the watershed, and the formulation of alternative strategies to address these sources. This effort is being coordinated with a broad range of stakeholder groups to address required actions and achievable water quality improvements. The following sections outline the scope of this effort.

Issue Identification and Communications

Representatives from key stakeholders are participating in a Steering Committee (SC). The SC is charged with developing the study goals and objectives into a project scope. The SC selected technical personnel from the stakeholders group to form a Technical Committee (TC). The TC's purpose is to determine how the goals and objectives will be addressed and to resolve the technical issues identified. An Educational Committee (EC) also was developed to help educate the citizens at large about the environment and how they can help to improve the water quality. The following organizations and agencies are participating in the watershed management plan:

- The Montgomery Water & Sewer Board
- EPA, Region IV
- U.S. Geological Survey
- Montgomery County and State Health Dept.
- Alabama Water Watch
- Alabama Society of Civil Engineers
- Montgomery County Commission
- Geological Survey of Alabama
- Auburn University at Montgomery
- Alabama Cattleman's Association

- Alabama Forestry Commission
- Alabama Dept. of Environmental Management
- Natural Resource Conservation Service
- City of Montgomery
- Homebuilders Association of Alabama
- Alabama Environmental Council
- National Society of Professional Engineers
- CH2M HILL
- Montgomery County Extension Service
- Army Corps of Engineers
- Alabama Dept. of Transportation

Pollutant Source Identification

The pollutants to be targeted are being determined by the SC and TC and will include parameters such as fecal coliform, sediment, nutrients, and metals. For each identified target pollutant, potential sources will be identified and mapped using the Board's Geographic Information System (GIS). Urban, agricultural, and other point and nonpoint pollutant sources identified by the committees will be investigated. Target pollutant loadings from each source for each target pollutant will be estimated using existing data summaries and documentation, areal yield rates, and modeling.

The existing water quality of Catoma Creek also will be evaluated. Existing data, especially from the previous water quality study and the local Water Watch Organization (voluntary organization conducting sampling along Catoma Creek), will be combined with biological sampling data and habitat assessment to perform the evaluation.

Potential for Control of Pollutant Sources

Control Technology Assessment. Control technologies will be identified for each target pollutant and source. Examples of the controls that may be identified are as follows:

- SSO Controls-Storage
    - Treatment
    - Infiltration/Inflow Removal
    - Public Education
    - Private Property Lateral Rehab
- On-site Waste Disposal Controls
    - Sewer Extension
    - Rehabilitation
    - Development Control and Conditions
- Storm Water Controls
    - Source Controls
    - Structural Controls
- Landfill Controls
    - Runoff Management
    - Debris Control
- Agricultural Controls
    - Cropland/Erosion Control
    - Animal Waste Management

The control technologies identified above will be evaluated for pollutant removal effectiveness, cost, and implementation issues for each target pollutant. A relationship between pollutant removal effectiveness and cost will be developed for each pollutant. In addition, implementation concerns such as regulations, training requirements, communications, and monitoring/long-term evaluation will be considered.

Water Quality Assessment. After target pollutant sources and controls have been identified, the anticipated water quality improvement will be predicted based on implementation of each control technology. Issues to be considered include whether the analysis time frame is by single storm events or over a continuous basis, and the measure of the relationship between pollutant removal and water quality improvement. Water quality modeling may be conducted to perform some elements of this task.

A major goal is to improve the water quality at the lowest cost. To do this, a combination of control scenarios will be developed. The effectiveness of each scenario will be projected and related to the water quality improvements expected for Catoma Creek. A cost for each scenario will be determined so that a cost versus water quality improvement relationship for each pollutant can be developed. The cost analysis can also be used within the context of a "pollutant trading" concept to meet water quality objectives while minimizing costs.

Alternatives Formulation and Decision Analysis

Following completion of the analysis of various control technologies, combinations of these technologies will be used to define alternative management strategies. These strategies will be reviewed with the TC and revised appropriately. Information regarding implementation costs and projected water quality improvement will be developed for each alternative management strategy. Final evaluation of alternatives will be done jointly with the TC and SC to reflect the insight of all stakeholders in the decision-making process.

Regulatory Framework for Watershed Plan

Existing state water quality standards will be evaluated and compared to the projected water quality improvements under the various control scenarios. An attainable water quality target will be determined based on technically feasible projected water quality improvements.

Recommended Watershed Plan

Scheduled workshops will be held with the SC and TC throughout the study to develop concepts and to reach concurrence on control approaches. These workshops will be used to evaluate controls and the corresponding issues that will be required to obtain the desired attainable water quality. Issues such as costs, training and implementation requirements, and the need for long-term monitoring and evaluation also will be considered.

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Summary of Proposed Stormwater Management Techniques for The Village of Woodsong as of January 31, 1996

Buddy Milliken

Intent

The intent of the stormwater management design is to resolve the challenge of creating a compact, higher density neighborhood based on New Urbanism principles, near a wetland forest area, while maintaining high water quality consistent with Sustainability principles. We are attempting to mitigate stormwater runoff at its source to the greatest extent possible and then conveying the excess through a hierarchy of incremental treatment, rather than relying solely on a centralized "end of the pipe" approach.

In order to receive credit from regulators for these incremental techniques as a substitution for end-of-the-pipe detention pond capacity, we have to quantify their effects. This is a real challenge for some of the more subjective components, but we are working through this as well. One thing that we don't want are environmental novelties that sound good, but don't work in the real world and/or are to expensive or complicated to have any wider application. Some of our first "epiphanies" haven't survived the final cut after more patient consideration, but at least we know why they weren't used. The distillation process has caused changes to some of our original methods, but the final techniques have to make environmental, social and financial sense. The design is about finished and application for a stormwater permit will be submitted the first part of February 1996. We will continue to monitor the function of system designed and modify it if needed for future phases. Two subsurface wells are in place in the wetlands and water samples have been taken from the creek at the property boundary. This will give us some baseline data to evaluate the effect on water quality of developing the site. Criticism or advice from the reader is welcome. For more technical information you may call our environmental designer, Mike Ortosky, ASLA at 919-571-1189 or our civil engineer, Jay R. Houston, P.E. at 910-754-6324.

Private Lot

Each lot owner will have to submit a plan outlining his particular stormwater approach as part of the landscape review process. An impervious square foot limit for each lot will be set as required by state regulations. All detention components will be sized based on these limits. The limits on typical lots for detached houses will be in the 60-70% range of total lot square footage. For those owners who wish to create more impervious surface, they will have the option to do by using on-lot detention methods such as "cookie sheets"(described below in #1), cisterns, etc. These lots are compact and the impervious limits are not overly generous, so we have to make sure the lots are functional and that we provide flexibility for the homeowners.

Ideally, homeowners would limit impervious surface to the prescribed limits plus use the on-lot detention methods mentioned. This would help get more of the water into the soil where it fell. As a developer, I am exploring ways to encourage the use of the techniques via a proposed demonstration house and possibly donating all or part of the cost of cisterns to residents. The degree of encouragement versus mandate for use of these techniques is still being refined and discussed with regulatory officials.

On-Lot Detention Methods

1. "Cookie Sheets" retain as much water as possible on the site up to the "nuisance ponding" threshold by creating shallow infiltration basins (similar in profile to a cookie sheet) out of the unimproved rectilinear portions of the lot with overflow directed through weirs to the front of the lot for dispersed sheet flow onto the grassed street margin. The infiltration basins could be bordered by low soil berms, bricks or wooden timbers. Because of a high water table we have little opportunity for deeper infiltration sand/peat bed storage. Each lot though, can be evaluated for suitability for a particular technique. For homeowners who may perceive a ponding problem, the benefits of this technique are; less water needed for irrigation because of groundwater recharge and the possibility for use of the water in courtyard gardens as a design element.
2. Use of cisterns with overflow capabilities in high flows and valving to provide the option of using stored water for drip irrigation to serve planted areas and gardens in dry times. The cistern is also being explored as an architectural element to help define "outdoor rooms" of the lot. Manufacture of cisterns in other areas has evolved into a local cottage industry and we would encourage that as well.
3. Use plants at the roof drip-lines which have a high capacity for vertical water storage and "leaf architecture" that intercepts a small percentage of runoff and traps it for eventual evaporation. A series of these tiers cascading to the ground could contribute to the whole "stormwater ensemble". However, this component is probably the most problematical, least quantifiable and practically most difficult to predict efficacy for. Regardless, it is worth being aware of as one more tool in the box.
4. The lot configuration and rear yard setback requirements for separation between the garage/apartment and the primary dwelling incentivize multi-story houses which require less

impervious roof surface for the same amount of square footage as compared with a single story house.

Street

1. At the street, we explored in depth an approach that called for slightly warping the grass margins to nudge the majority of excess residential runoff into shallow aggregate filled pits near the trees. The trees are spaced ev ery 30 feet on both sides of the road and were thought to have a significant cumulative storage capacity. However, this method has been deleted because of the following: a) concerns about the long term health of the trees and the potential migration of roots into the pits over time, b) a high overall water table means that the pits would have to be very shallow. This would be compounded because the land will be sloped slightly as you move from the front of the lots toward the grass margins and street travel surface. Any grade cut required, would diminish the storage potential of the pits even further, c) maintenance and vulnerability to mischievous disturbance of the surface aggregate were also thought to be potential problems, d) Lastly, it was more difficult to quantify its detention contribution to regulators.

   Having said all that, I still think it could be a good technique where the water table is lower, tolerant trees are selected and there is some mitigation for the risk of root migration into the storage pit areas. In a condition where the planting strip is not being used for parking, the storage pits could be located farther away from the trees in the grass margins and incorporated into swales. A minimum approach would be to utilize the technique wherever the natural topography around the tree suggests it.
2. The street is presently designed to be slightly inverted (reverse crown) with catch basins and underground pipe located in the center of the street. The inverted street allows for a seamless transition for a pedestrian on the street walking to the front porch and provides an almost level grassed slope that serves as on-street visitor parking, but when not parked on, looks like a planted strip instead of vacant asphalt. This approach eliminated the need for 16 feet of paved parking surface (8' on each side) and 10 feet of sidewalk (5' feet on each side). The drawbacks are that grass swales can't be used for street runoff because the slopes would impair the use of the street margin for parking or walking. It does seem however, that increasing the impervious surface from an 18 foot wide travel surface to a total impervious surface of 44 feet wide in order to utilize grass swales is not productive. A more insidious problem is that the social distance of engagement between pedestrians and porch sitters would have been compromised as well as the "human scale" and spatial intimacy of the street as an outdoor room.

   While an inverted street utilizes existing asphalt for a non-erosive conveyance channel, it makes it difficult to get any treatment of the street runoff before it is piped down to the detention pond and the inverted profile probably makes porous asphalt paving infeasible because of sediment migration onto the paved surface. The main virtue of this design is that it simply results in less impervious surface. We are exploring the use of a trial area of porous concrete pavers in the first phase. I am waiting on regulators to provide me with some guidance on a test of this approach for

reducing runoff volumes otherwise required to be collected in a detention component. The streets will be part of the city system and there are some constraints on the use of unconventional paving materials because of that. In summary, if used at all, we will have to transition into the use of porous paving methods by phased tests in order to obtain regulatory credit for the technique and provide a level of comfort to the city.

Biofilter

Along the northwestern boundary there is continuous wooded land that will remain undeveloped except for a portion which will be a children's park. In the children's park we plan to change from subsurface solid-pipe conveyance of stormwater to overland flow through the "biofilter". We are proposing to convey the surface runoff collected from the nearby street and direct it along a fairly linear, but twisting, shallow conveyance channel that will essentially be a constructed wetland with mic- ropools on either end. The channel will provide some infiltration along the way, but will mainly be for conveyance. We don't want to end up with a park that is more of a utility than a social environment. The water will be slowed down so it can be filtered as it spreads slowly over soil and plants during moderate flows. In high flows, the channel will provide a durable conveyance. This linear wetland will be integrated into the park as a shallow creek for children to play near and will replace some wildlife habitat being eliminated by the developed areas.

Level Spreader

Collected surface water was examined for dispersion by using a level spreader approach. Around the perimeter of the vegetative buffer forward of the primary pond, a level spreader was explored in the form of a semicircular curb, possibly of concrete, which would have a progression of smaller to larger openings as you move away from the concentrated surface flow . Because surface flow coming into this area is not that great, this approach is not being used. At minimum, we can evaluate the effects of the channelized flow into this area after construction and retrofit specifically as needed. A subsurface aggregate-filled trench was examined, but discarded because of the water table, a lack of soil porosity and also a lack of distance between the pond and street to allow for adequate filtering through slow subsurface migration.

Subsurface Detention Pipe

In areas where a pond might become a safety hazard or contribute very little aesthetically to the neighborhood, we are using subsurface pipe as storage to achieve the required detention. We are looking at doing this in one of the small parks which has a high degree of imperviousness bordering it, and under a parking lot that would receive runoff from the "Biofilter Conveyance". I would rather use a more natural detention method but nothing else appears feasible. It does provide us with the ability to phase in detention as needed by simply adding more pipe as needed. Our detention pond on the other hand has to built all at once, even though it will be underutilized in the first and second phases.

Detention Pond

There will be a conventional detention pond of approximately 1/2 acre in size. The pond excavation will include about .06 acres of wetlands. The pond will have a vegetated forebay and littoral bench that to some degree will be a substitution of another form of wetland for the portion of the existing wetland being excavated. The pond will provide a primary aesthetic purpose too by serving as a prominent neighborhood gathering spot. An in-stream location for detention was discus sed, but rejected because of concerns about changing the hydrology for adjacent landowners.

Wetlands Gabions

A previous owner of the land had dug a fairly straight, steep ditch through the middle of the wetlands. We plan to use gabions to dam up the ditches in strategic areas and to some degree recreate the wetlands hydrology and function in place before the ditch was dug. The stormwater detention pond outflow will travel into the shallow pools created by the gabions, where it will take a more serpentine path through a variety of vegetation before leaving the site. We are also exploring the transplanting of excavated biomass and wetlands vegetation from the Detention Pond to use as fill material in the ditches between the gabions. We have to have somewhere to put the material anyhow. Ideally, each construction by-product should be "food" for another process. Recovery and recycling of living materials will need to be done quickly and properly though, if the desired effect is to be achieved. The gabions themselves are envisioned to be constructed of stones or rocks near the ditch bottoms to wit hstand high velocities and comprised of more natural materials such as soil, stumps, etc. woven together the closer to grade you get, so that eventually it will be impossible to detect the gabions have been inserted. We think that there will be a net increase in wetlands after installation, because the ditch is on the perimeter of the current delineated wetland. It should also enhance the functional capability of the wetland. Of course, as a result of development, we are certainly asking it to do more. The ga bion technique is a kind of landscape archaeology and probably comes closest to the ideal of development as an act of repair. It may have some quantifiable regulatory detention credit as well, but this remains uncertain at this point.

New Urbanism Pattern of Development

All previous descriptions have been about on-site measures. The greatest potential benefit of all the techniques though, is the clustered form of development. On a regional scale it has the potential to dramatical ly reduce future construction of impervious highway infrastructure as well as reduce the automobile-deposited pollution on roads by providing alternative transportation choices. Even though imperviousness is concentrated at the site, this pattern if implemented, will preserve abundant open space and consume far less land than low-density patterns. Coupled with the application of Sustainability principles, New Urbanism can be a great tool for improving regional water quality in addition to its social and cultural benefits.

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The Economics of Open Space

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Open Space is often seen as a cost to the community_the cost of acquisition, the cost of facility construction, and the cost of maintenance. However, open space also has a benefit to the community, a tangible, economic benefit. Trees and open space, whether public parkland or privately owned farmland and recreation areas, are our communities' most precious resources. As with all natural and scenic resources, it is important to conserve them since once gone, they are often lost forever.

Within the world of business and development, the organizing force is the bottom line_how profitable will this business or development be for its inventors? The economic bottom line is often used as the reason for opposing conservation regulations, and maximizing the development of land. But there is a growing body of evidence that shows that resource conservation, particularly trees and open space, are both economically and socially beneficial for the community and that conservation is important to the bottom line of business and development. This session will explore the balance of the costs and benefits of open space, providing an economic bottom line to the issue of providing public and private open space in a community.

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Moving the Watershed Planning Process from Quagmire to Success

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In developing watershed management strategies, scientific observation and engineering analysis are balanced by social values and goals. Resource management planning often takes place in a hot house climate of conflicting views that are strongly held and passionately argued. These are based on a mixture of science, romanticism, personal philosophy, and economic need. The result can be paralysis in the decision making process. The size of a region, the diversity and complexity of its environment, the breadth of interests, and the difficulty of having sufficient good data for supporting decisions are also major contributors to programmatic inertia.

It is fruitless to hope that we will discover simple, elegant, and universal answers to resource management questions. There are two reasons for this. First, complexity, variability, and diversity are hallmarks of the natural environment we seek to manage. At the same time, a wide spectrum of human interests extends across and intertwines with this far-from-simple environment. Therefore, management will be a perpetual and open-ended process of discovery and compromise, of substantial successes and occasional backsliding. A sound management approach is one that can address ambiguity and uncertainty. Ambiguity comes from conflicting values and directives; uncertainty comes from the failure of a program to be definitive.

Ecosystem management programs have been implemented in all parts of the country. Two well established programs in the East are in the New Jersey Pinelands and the Chesapeake Bay. These are

among the most informative models because of their relatively long histories. In the Northwest, issues of forestry, fisheries, and species protection are energizing moves to develop integrated resource plans that achieve multiple objectives. The Pinelands and Chesapeake Bay experiences demonstrate the value of some guiding principles that any program would be well advised to adopt. These basic rules, which will help a watershed management program avoid the quagmire that is always near at hand, are:

- Clearly expressed needs.
- Clearly expressed goals.
- Good research.
- An open climate for discussion of issues.
- Genuine partnerships among stakeholders.

Those involved in establishing and nurturing a watershed management program must address a number of subjects. If left unattended, these can slow a program or derail it altogether. Keeping out of the quagmire and on the road to success requires appropriate attention to these:

- Trust. A major hurdle to moving a program forward to implementation is trust in leaders and trust that the process will empower people to work together to define and achieve common goals.
- Discovering Leaders. Traditional elected and appointed leaders may have less well-defined roles and authority than in the past.
- Definition of Roles. Responsibility and authority may be unclear when there are conflicting mandates and unforeseen gaps in authority or responsibility.
- Changing Roles. The identity and roles of various stakeholders are difficult to determine and may change as a program evolves.
- Lack of Clarity. It is difficult to establish a clear vision or image of what a complex ecosystem is and how it directly affects or benefits people.
- Problem Definition. Failure to define the correct problem due to a lack of a systematic process or wrong stakeholders can waste a lot of time and resources.
- Persistence. Long-term planning horizons are difficult to reconcile with the short attention span of political bodies and the public.

- Abstraction and Size of Effort. Large scale programs with multiple objectives and intricate interrelationships are too abstract to sustain attention.

- Good Data from Good Science. Good science is important to defining systems and their critical control factors, and to framing management options.

- Separation of Science and Policy. Distinctions between science and policy are often confused or obscured when developing alternatives and making decisions.

- Urgency. Management programs are difficult to implement without a crisis.

- Measures of Success. Success is exceedingly difficult to measure in the time frame that most people expect to see results.

Successful management program leaders:

- Establish and reinforce credibility.

- Have a clear vision and a set of specific and comprehensive goals.

- Empower stakeholders and ensure an open climate for debate.

- Work to ensure that funding and resources are available.

- Identify the limits of a problem.

- Insist on a systematic decision process.

- Repeatedly demonstrate their commitment to the process and to the solutions selected.

In the Chesapeake, for example, twelve public officials, elected politicians, academics, lawyers, and developers were appointed by their respective governors to a panel of experts to address population growth and its impacts. All were leaders in their own right, but worked together to achieve a consensus, and then returned to their leadership roles in their own communities. The group was able to take advantage of the leadership qualities of each person. Each person was able to contribute based on his or her leadership qualities, but did not seek to dominate.

In ecosystem management programs, leadership can come from any quarter. In both the Chesapeake and the Pinelands leaders are fishermen, businessmen, developers, farmers, environmentalists and citizens, as well as public officials. They listen well. They ensure an open climate for transfer of insights and opinions and are not overly directive of the process. They are patient in the definition of problems and in

the selection and use of data. They are open to the opinions of others. They are willing to deal with uncertainty and look at alternative outcomes. Successful leaders also have the authority and ability to bring the necessary resources to bear when they are needed. Once momentum has developed in a program, leaders provide the resources needed to maintain it.

In programs that cross jurisdictions and responsibilities, there are ill-defined lines of authority. As agencies work cooperatively and jointly, their roles are based more on a "natural" authority and are less defined by agency traditions. Setting goals and objectives that are broader than their mandate will be difficult for individual agencies; they will need to rely on the good offices and efforts of others to achieve their aims. Leaders within these agencies will need to find new ways to empower groups to work together.

Successful program managers:

- Understand the functioning and critical control points of their ecosystems.
- Maintain state-of-the-art research efforts.
- Make policy decisions based on the best science available at the moment.
- Monitor and reassess policy decisions.
- Demonstrate expertise.

Ecosystem management must build on observational, analytical, and experimental science. Policy decisions have little chance of being sustained without a good foundation in science. Scientific study is needed to define system boundaries and describe a system's functions. These findings lead to the identification of critical elements for management and control. One risk is that becoming enmeshed in the complexity of ecosystem analysis can become an end in itself, a refuge from confronting tough management choices.

There is often a flow of personnel between the scientific and policy communities. The difference between the role of science and the role of policy can get blurred and confused. Because science is so important in understanding a system and the consequences of different actions, scientific arguments often appear to take the place of public policy. Policy must be based upon the best scientific information, but must be clearly separated from scientific judgment. Policy weighs scientific information along with social objectives and the ethical and philosophical concepts abroad at the time. Programs must be willing to reexamine earlier policy decisions in light of new information.

Successful programs:

- Have goals that are embraced by leaders at all levels of government, the community, and

business.

- Ensure that diverse participants are brought into the process early, have a generous opportunity to participate, and are afforded a productive long-term role.

- Maintain continual public and institutional education programs.

Leaders and managers cannot develop, monitor, revise, and implement a program alone. No single landowner, organization, or community can implement a broad-based program alone. Everyone shares responsibility for getting extraordinary things done through ordinary means.

The Pinelands program, the Chesapeake Bay program, and similar programs everywhere, undergo continual examination as a normal part of political processes. Some interests, generally those not extensively involved in building a program, are continually pressing for their particular objective or view. Because of their broad support and extensive public involvement, both the Chesapeake and the Pinelands have withstood these challenges with good success. However, their battle is never-ending.

Unfortunately, it is difficult energize a program without a crisis. A major challenge in watershed management will be to continually educate people about why certain practices and activities are necessary, especially those that affect people's livelihoods, their recreation, or their use of the land. Both the Pinelands and the Chesapeake Bay Programs have found ways to get ecosystem management accepted into the social and institutional fabric of their respective areas. While there is no set formula, successful programs appear to have several common characteristics. These include patience to allow the programs to mature and the constant involvement of people at all levels of planning and implementation.

The public should be involved in the process of developing a program from the start, and its role should be maintained throughout the decision process. This is a key element in successful programs. It is difficult to include all interests and a diversity of viewpoints, but this is necessary for a program to be credible and to become an accepted and adopted way of behaving and thinking about the managed resources. The quality and openness of a decision process are nearly as important as the quality of the results. Even with a host of decision tools and a stack of scientific reports, decision making remains fundamentally a human process subject to human error, bias, and plain folly.

Few people are trained in decision making. Most rely heavily on old habits or simplifications. These often lead to the adoption of advocacy or adversarial processes, rather than genuine problem solving and decision processes. Success is highly unlikely in the absence of a systematic decision processes that frames problems well and identifies a comprehensive set of alternative actions. In both the Pinelands and the Chesapeake Bay, framing problems correctly was difficult. It required more time and effort than people anticipated.

A good decision process:

- Details goals, objectives, and values.
- Distinguishes the roles of science and policy making.
- Emphasizes which data are important to problem solving and decision making.
- Establishes a traceable and open record.
- Achieves credible results.

Measuring success is difficult in natural resource management, since there is no end point to a program. Both the Pinelands and Chesapeake Bay Programs have been working on research to show progress because most objectives are long-term, with results off in the future. Rapid, dramatic results are infrequent. Efforts to develop and publicize environmental "score cards" are helpful in maintaining the public's attention and interest. It is important to have a mix of both short-term and long-term goals to allow for early demonstration of progress.

In fact, most "programs" are not single programs at all, but clusters of strategies and independent programs and plans. These are worked out over time among a host of groups, within a generally accepted policy and goal framework. Funding for these individual efforts ebbs and flows. At the same time, the voluntary efforts of many individuals and groups play a significant role both in developing a public consciousness and in dealing directly with problems that are amenable to volunteer action.

The watershed restoration and forest management planning being undertaken in the Northwest illustrates many of these points. Concern and energy to undertake programs reaches to the grassroots in communities hard hit by the collapse of local resource-based economies. There is a need for partnerships among landowners and regulators to develop long-term strategies for land use and land protection. Incentives are needed, too, for private land managers to protect publicly-valued goods in the land. Jobs increasingly include working on restoration projects and other management programs as well as traditional resource-based employment.

This type of thinking goes beyond "interagency coordination". Resource agencies are themselves members of a larger resource team and must begin to bring their special knowledge to bear as members of the team. For instance, EPA is organizing to regulate impacts of concern to it on a watershed basis. Rather than segregating various pollutants by the medium the pollute, they are looking at integrated land-water-air solutions. Neighboring land owners, environmental groups, county agencies, and state and federal resource agencies are seeking voluntary collaborations to create plans for watersheds. This is happening in rural and urban areas alike.

A clear example of bringing diverse parties together to review and explore options was the Northwest Watershed Restoration Conference sponsored by Congressman Norm Dicks in Tacoma, Washington in 1994. Central messages coming from the conference are applicable elsewhere:

- Watershed restoration will not be controlled by a central authority; it will be the result of a number of public/private programs.
- Local political and opinion leaders must be involved.
- Public agencies must abandon some of their traditional management focus and share resources, experience, and data.
- Agencies have an opportunity to develop new project delivery systems to ensure that work is accomplished in a timely manner and that local skills are developed and used in practical management solutions.

Resource decisions are shaped by both technical considerations and individual or collective values. The concept of balancing technical and social inputs is central to resource management. For instance, knowledge of technical issues, such as development cost, risk, environmental impact, quality, and reliability, is essential to development of, say, a well-informed water supply plan. But, this technical knowledge alone does not determine the plan's final shape. The most viable alternatives are those that have successfully balanced technical and economic criteria with local, regional, and national values.

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Facilitating Natural Resource Dialogues on a Watershed Basis

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Historical Background

When Congress passed the federal Clean Water Act amendments in 1972, they focused on the pollution stemming from "point sources," as natural targets in a command and control style regulatory regime. The amendments required that "point sources" achieve maximum "effluent limitations," as well as comply with acceptable water quality standards. In addition, the amendments established the National Pollutant Discharge Elimination System (NPDES) permitting scheme as a means of enforcing those effluent limitations. This command and control system has achieved significant progress in regulating point source pollution, such as heavy industry and other discrete pollution sources, for over twenty years.1

Nonetheless, recent water quality surveys still indicate areas of concern, particularly with respect to agricultural pollution and nonpoint sources. As reported in the 1992 report The Quality of Our Nation's Water, many water quality and habitat degradation issues still present a challenge. One third of the nation's waters do not support designated uses. "In the one third of assessed waters that have water quality problems, the leading contributors to problems are agricultural runoff, municipal sewage treatment plant discharges, storm sewer and urban runoff. Agricultural runoff is the most extensive source of pollution in the Nation's waters."2 Addressing these remaining sources demands that policy makers initiate new approaches for handling pollution problems. Essentially, the problem stems from the fact that diffuse sources do not lend themselves to command and control style oversight. Instead of attending to the effluent discharged by obvious sources with discrete pipes, regulators face endless miles of fields and cropland dispersing runoff during random rainfall events. As Dana Rasmussen, Regional

Administrator for EPA Region X, observes,

[t]he widespread problem of nonpoint source pollution-runoff and deposition of air pollution to land and water . . . underscores the limits of effective enforcement. Our society does not have the resources to police each citizen's behavior and lifestyle in order to prevent or punish our polluting habits.3

New Approaches

Watershed Management and Stakeholder Participation

The Environmental Protection Agency recognizes the need for new frameworks capable of addressing land use management issues over vast areas. In order to handle remaining pollution issues and build upon progress achieved thus far, EPA has promoted a watershed approach for water quality management. EPA has articulated its evolving vision in Watershed Approach Framework-1996: "people working together to achieve clean and safe water and healthy aquatic ecosystems through comprehensive management approaches tailored to the needs within watersheds."4 The involvement of people, then, constitutes a crucial element in any watershed approach. As the Framework emphasizes,

Broad involvement is critical; the watershed approach relies on community-based environmental protection. In many cases, the solutions to water resource problems depend on voluntary actions on the part of many people. Besides improving coordination among their own agencies, the watershed approach calls upon states . . . to fully engage local government and other affected parties in the watershed management process to help them better understand the problems, identify goals, select priorities, and choose and implement solutions.5

For these reasons, EPA encourages the formation of watershed management teams and partnerships. Only through watershed teams may the new frontier of nonpoint sources receive adequate treatment.

Using Lessons from Coordinated Resource Management (CRM)

Facilitating dialogues among diverse members of the watershed community requires a viable framework for encouraging cooperation. CRM offers a number of important lessons for this process. CRM is a concept used to resolve specific conflicts involving natural resource management. CRM establishes a level playing field for a variety of landowners, in a specific watershed, to discuss and reach consensus on the best method for framing a watershed plan to reduce pollution loadings. The Bureau of Land Management, Forest Service and the Cooperative Extension Service have used CRM in the management of public land for many years. "The process . . . has been used successfully to resolve specific resource-use conflicts, such as depredation of agricultural crops by wintering geese near waterfowl refuges and water contamination from dairy farm lagoons and livestock feedlots."6

Initiating a CRM effort begins at the local level. "Preferably, a coordinated plan is initiated at the local

level by a request from a . . . organization . . . that perceives the need for a group-action approach to resolving or averting a local resource problem. A conservation district, for example, might process a request for a coordinated plan because these districts are legal subdivisions of state government with responsibility for land and water conservation."7 Thus, local soil and water conservation districts can trigger the utilization of CRM style initiatives in order to formulate watershed plans.

Local soil and water conservation districts (LCDs) may then call together a broad range of participants, incorporating representatives of those agencies, organizations, and associations having a direct interest in the resource management issue at hand. CRM recognizes that "the whole community should work together as a team from the beginning to the end of any planning effort. This assures the greatest number of ideas, the widest range of options and the very best courses of action in the interest of the community as a whole."8 In addition, embracing the full range of actors in a watershed increases the likelihood that planning decisions will be implemented effectively.

Watershed participants meet in a group called the Steering Committee (SC), consisting of approximately 20 management level representatives. They are decision makers who can speak for their organizations on matters dealing with watershed planning. When technical issues arise, the SC seeks out the assistance of Technical Review Teams (TRT). "TRTs usually function at the ranch unit, allotment, small watershed, wildlife, wilderness, or similarly sized area. They are composed of interdisciplinary technical experts, landowners, permittee, agencies and interest groups as appropriate for the subjects and issues at hand."9 A field trip of the local area by watershed participants begins the process of introducing stakeholders to each other and breaking down barriers.

CRM forums, such as the steering committee, allow all involved parties to vent frustration and be heard. Land use and property rights issues generate a very strong emotional response among watershed stakeholders. Within a proper framework, however, this group can yield diverse options for resolving conflict. A facilitator plays a crucial role in this process. A facilitator is a neutral person that provides structure to the meeting and keeps everyone involved. Lessons from formal mediation principles and CRM establish the framework for guiding a productive discussion. The guiding principles for such a meeting, include:10

1. Involve only the real players in the conflict. All interested parties must be included in the planning group to insure productive discussion and implementation of decisions. "To leave some caring interest out is to invite attack."11
2. Identify the problem. All parties must agree on the real problems and issues. Over time, this will allow hidden agendas to be brought to the surface.
3. State Expectations and Objectives. Each member of the meeting should state what they want from the meeting. Many times members have shared goals, such as preserving the resource. This establishes common ground and a means for moving forward. Where desires differ, the areas of concern are clear.
4. Analyze the problem. All aspects of the issue should be discussed. This is the point where solutions can be examined and options generated.
5. Make decisions by Consensus. The committee takes all decisions, recommendations, and actions

by unanimous agreement. "Any issue not receiving unanimous resolution would be sent back to a working committee for further study or would be tabled."12 Many find the consensus rule generates trust and responsibility among watershed participants. In working on a CRM project dealing with grazing on public lands, John Weber observed "The consensus rule has been extremely important to our success story. It has developed confidence and trust."13

6. Agreement. All parties must agree on the best management of the resource. This results in the formulation of the watershed plan.

Applying These Concepts, Planned Intervention

The Texas Institute for Applied Environmental Research (TIAER) has developed an approach which harnesses evolving priorities; it avoids the narrow confines of command and control regulation and feeds into the concept of watershed teams and partnerships. It is entitled planned intervention.14 It emphasizes a deliberate, well-planned combination of voluntary measures, against a regulatory backdrop. Voluntary programs, alone, have failed to produce significant reductions in agricultural nonpoint source pollution.15 EPA observes that, "[t]he trend in nonpoint source control is towards voluntary approaches as the primary means for best management practice (BMP) implementation and regulatory and quasi-regulatory approaches as a backup means."16 Under planned intervention, individual agricultural producers adopt best management practices, guided by recommendations made through advisory bodies consisting of local stakeholders. The Texas State and Soil Water Conservation Board (TSSWCB) cooperates with producers to develop corrective action plans should pollution complaints occur.17 Where "bad actors" refuse to cooperate, they are referred to the environmental regulatory agency for enforcement action.18 Thus, planned intervention envisions close cooperation between environmental regulators, LCDs, individual producers and other local citizens. Properly linking the pollution abatement efforts of natural resource agencies developed during the "New Deal" with regulatory programs allows policy makers to exploit the strengths of both. Planned intervention became the law in Texas in 1993.19

Citizen participation provides an integral element in the planned intervention/micro-watershed approach. TIAER has convened a "constituency committee" consisting of local stakeholders in order to facilitate a dialogue on the Lake Waco/Bosque River watershed and water quality issues. This committee includes representatives of all true stakeholder groups, e.g., dairies, municipalities, riparian landowners and local environmental interest groups. The committee is chaired by several elected representatives, whose districts overlay the watershed. It is important to include such vital decision makers in the process; one wants to involve leaders interested in environmental quality in the watershed and perceived as capable of promoting constructive policy change. A number of groups have committed to playing an important role in this committee: TIAER, TSSWCB, Texas Natural Resource Conservation Commission (TNRCC), Brazos River Authority (BRA), Extension Service, United States Department of Agriculture Natural Resource Conservation Service (USDA/NRCS), and local conservation districts.

At the local level, LCDs will take the lead in facilitating the implementation of the "planned intervention/micro-watershed" strategy. In those micro-watersheds producing excessive pollution loadings, LCDs organize stakeholders into consortia where members collectively discuss pollution problems and assist in the development of solutions for reducing pollution loads. Consortia will include no more stakeholders than can meet face to face for collective deliberation. Periodic meetings over the course of the project will allow consortia members to develop rapport. The goal of consortia meetings is to inform the development of a micro-watershed plan that will reduce pollution loadings to target levels. Each of these forums will benefit by utilizing the lessons from CRM and mediation techniques.

Endnotes

1. See Peter Rogers, America's Water Federal Roles and Responsibilities 4 (1993).

2. EPA Fact Sheet, National Water Quality Inventory 1992 Report to Congress-EPA841-F-94-002 (April 1994) at 2.

3. Dana A. Rasmussen, Enforcement in the U.S. Environmental Protection Agency: Balancing the Carrots and the Sticks, 22 Envtl. L. 333, 336 (199l).

4. The Clean Water Act: New Directions, ABA Satellite Seminar-Jan. 18, 1996, Watershed Approach Framework at 57.

5. Id. at 61.

6. E. William Anderson, How to do Coordinated Resource Management Planning, J. of Soil and Water Conservation, Vol. 43 No. 3, May-June 1988, reprinted in Coordinated Resource Management Guidelines 7-5 (Society for Range Managment, June 1993).

7. Id.

8. C. Rex Cleary and Dennis Phillippi, Society for Range Management, Coordinated Resource Management Guidelines 4-9 (Society for Range Management Guidelines, June 1993).

9. Id. at 5-1.

10. Bill Ross, a policy intern at TIAER, aided in the formulation of these guiding principles.

11. C. Rex Cleary and Dennis Phillippi, supra note 8, at 7-3.

12. C. Rex Cleary, Experimental Stewardship-What's happening?, Rangelands, Vol. 6 No. 4, Aug 1984 at 167, reprinted in Coordinated Resource Management Guidelines 4-16 (Society for Range Managment, June 1993).

13. Guy Webster, Old Foes working together to help manage public lands, Reno Gazette-Journal, June 3, 1984, reprinted in Coordinated Resource Management Guidelines 4-14 (Society for Range Managment, June 1993).

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15. Logan, Agricultural Best Management Practices: Implications for Groundwater Protection, 5 Groundwater and Public Policy 6 (199l).

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17. Id.

18. Id.

19. V.T.C.A., Agriculture Code § 201.026 (1996) et. seq.

Acronyms

BMP Best Management Practice

BRA Brazos River Authority

CRM Coordinated Resource Management

EPA Environmental Protection Agency

LCDs Local Soil and Water Conservation Districts

NPDES National Pollutant Discharge Elimin ation System

SC Steering Committee

TIAER Texas Institute for Applied Environmental Research

TNRCC Texas Natural Resource Conservation Commission

TRT Technical Review Teams

TSSWCB Texas State Soil and Water Conservation District

USDA/NRCS United States Department of Agriculture Natural Resource Conservation Service

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Describing the Elephant: Multiple Perspectives in New York City's Watershed Protection Conflict

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Introduction

New York City's efforts to avoid filtration mandated by the 1986 Safe Drinking Water Act Amendments and the 1989 Surface Water Treatment Rule have generated considerable controversy. Since the conflict began in 1990, a spectrum of stakeholder groups has emerged, representing land owners, sport fishermen, businesses, environmental groups, developers, and watershed communities. What was originally defined by New York City water supply managers as a scientific problem--identifying sources of water quality degradation and preventing contaminants from entering the water supply system--now has broadened to include a diverse set of social and economic issues as well.

The debate itself has been polarized by heated rhetoric, hyperbole, and simplistic characterizations of the issues and actors. Stakeholders have created caricatures of good guys and bad guys, painting each other variously as "greedy developers who just want to retain their right to pollute", "rich and elitist environmentalists telling other people how to live", "obstructionist", "arrogant", "hick farmers", and "city slickers". Downstate proponents of watershed protection portray upstate watershed residents as unconcerned about the health of the millions served by the water system, wantonly destroying the environment to pursue selfish ends. Albert Appleton, former Commissioner of the New York City Department of Environmental Protection (DEP), set the stage early in the debate when he said: "I'm trying to protect water quality for nine million people, and if you're going to build in the Catskills in the future, you'll have to build in an environmentally responsible way." (Shaman, 1991) The rhetoric escalated when then-Mayor David Dinkins added: "It is absolutely asinine to let people pollute the water we're going to drink and we're not going to have it."(Wald, 1993) He was followed by City-based

environmental groups blaming upstate development interests for weakening watershed protection efforts, and raising the specter of watershed wastes ending up at New York City taps from 128,000 septic systems and more than 100 sewage treatment plants that ". . . dump into the reservoirs." (Golway, 1994) Such images effectively agitate water consumers like the one who jumped up at an informational meeting in the City and said: "These people are pooping in our water and we have to stop them!"

Upstate residents portray watershed protection proponents as aggressive conquerors insensitive to local lives. At a public hearing, one Catskills town supervisor likened the DEP to an occupying army. In a more moderate vein, another said: "We worked for this land. We paid for this land. We are the ones who pay taxes on this land, but then New York City comes in and calls it their watershed." At a different public hearing, another resident expressed the fears of some that the City's efforts are part of a larger conspiracy: "We believe that land-use regulations, . . . among numerous other things, are being woven tightly around us by government at all levels. And we believe . . . that at some point, when some bureaucrat somewhere far from these hills decides the time is right, this complicated fabric will be dropped over our heads, drawn tight around our ankles, and we will be toppled in a heap and dragged from our homes."

By emphasizing differences between stakeholder claims to watershed resources, the debate has obscured underlying differences in stakeholder perspectives. It also focused early efforts on trying to resolve conflicting claims rather than on seeking opportunities for mutually satisfactory solutions. Most of the five years of this conflict has been spent at the point of conflict, arguing over whose claim is more legitimate. It has only been in the last year, when the discussions have moved beyond the issues of claims to the views and values on which those claims are based, that there has been real movement toward a solution. Although it is easy to dismiss obviously exaggerated sentiments as mere battle tactics for one side or the other, I suggest that these be viewed instead as indicators of more fundamental and important differences in stakeholder perspectives.

In my observation of this conflict, I have come to see the parable of the blind men and the elephant as a metaphor for stakeholder differences. In this story, several blind men were asked to describe an elephant. One, standing by the elephant's leg, said the animal was as tall and straight as a tree; another, standing at the elephant's side said it was broad, flat and immovable, like a wall; another at its tail said the elephant was thin and flexible, like a rope. Their descriptions were extremely different, although they were describing the same thing. They saw it so differently because they were each looking at a different piece of it. I propose that this is similar to what happens in many environmental management disputes, and that exploring not just how, but why perceptions differ, can lead to a better basis for resolving disagreements about watershed management. This paper sets the context of New York City's watershed protection conflict, then briefly discusses some implications of the underlying differences in stakeholder perspectives.

Background

This discussion is derived from a four-year study of the New York City watershed protection conflict,

focused on the Catskill region watersheds. The study included over 130 interviews with watershed stakeholders, observation of more than 100 stakeholder meetings and public hearings, and a GIS-based study of hydrologically sensitive areas.

New York City's Water Supply System

The New York City DEP supplies an average of 1.5 billion gallons of water per day to approximately nine million consumers in New York City and neighboring communities. The water is drawn from 1,969 square miles of watershed lands (NYCDEP, n.d.), all located outside the city boundaries. Ten percent of the water comes from the Croton watershed system, approximately 50 miles north of the City. Ninety percent comes from watersheds in the Catskill Mountain region, roughly 100 miles north of Manhattan. The Catskill Mountain region, includes two watershed systems, the Catskill system and the Delaware system, and covers a total of 1,584 square miles (NYCDEP, 1995). Approximately 170,000 people live full-time in the Croton watersheds; 50,000 in the Catskill and Delaware watersheds (NYCDEP, 1993). The City owns just under seven percent of the watershed land, about half of which lies beneath its 18 reservoirs. Most of the City's watershed holdings are located around the reservoirs, protecting a narrow buffer at the water's edge. Approximately 25 percent of the remaining land, mostly in the Catskill and Delaware systems, is owned by New York State; the rest is privately held.

The water generally requires only minimal treatment before distribution. Its high quality has been attributed to its sources in the sparsely populated and largely forested Catskill Mountain watersheds. The DEP has the legal authority based on a 1905 New York State Public Health Law to regulate watershed land use to protect water quality. Before 1990, however, it had only used this authority to issue a very general set of guidelines in 1953.

Incentive for Watershed Protection

Federal law requires that all municipal surface water supplies be filtered unless the water meets federal drinking water standards and the water supplier shows it can prevent water quality degradation through watershed protection. Filtration of Catskill and Delaware system water would cost an estimated $5 to $8 billion, plus another $300 million per year in operating expenses. Hoping to obtain a filtration waiver, the DEP drafted land use regulations in 1990 as the foundation of a watershed protection plan. The 1990 discussion draft established buffers around reservoirs and along streams restricting activities such as the siting of septic systems. Buffers up to 1000 feet wide were originally proposed around reservoirs and up to 500 feet from stream channels (NYCDEP, 1990). Dairy farmers were required to prevent barnyard runoff from discharging to surface water and were prohibited from spreading manure within 100 feet of a watercourse. The regulations restricted the use of de-icing compounds on roads, limited impervious surfaces such as roofs and parking lots, and upgraded the technology and level of treatment required for wastewater treatment plants.

Stakeholder Groups

Stakeholder groups, (where a stakeholder is broadly defined as anyone who is either directly affected by or has expressed an interest in the watershed issues), started to form or take positions following the release of the 1990 draft regulations. Initially, the controversy seemed a straightforward clash of interests between the watershed and the City, but it quickly became more complicated. Neither watershed nor City interests are homogenous, and the DEP's watershed protection program expanded over time to include issues beyond land use regulation, including land acquisition, watershed planning, and a farm planning program. Stakeholder groups formed throughout the last five years as new issues emerged or were articulated. Stakeholders include: City water consumers; the DEP; government and public agency officials at village, town, county, City, state and federal levels; environmental organizations in the City and in the watersheds; City-based public health and low-income housing advocates; builder's associations; business associations; educational organizations; long-term watershed residents; farmers; tourism service providers; second-home owners; and recreational users of watershed land and streams. These diverse stakeholders are allied on some issues and at odds on others. The situation is further complicated because individuals may be part of more than one stakeholder group.

Over the last five years, stakeholder groups have disrupted watershed protection efforts through legal challenges and by mobilizing public opinion, and helped bring diverse issues to the discussion. In March 1995, when discussions between the DEP and the Coalition of Watershed Towns, a quasi-governmental organization representing the 35 towns in the Catskill/Delaware watersheds, seemed to have reached an impasse, New York State's Governor George Pataki convened a closed-door negotiation process to bring stakeholders together. The talks lasted seven months and concluded in early November with an "Agreement in Principle". While the Agreement is being praised for addressing the range of stakeholder concerns, all parties agree that its true test will be in designing and implementing its details.

Discussion

Looking at underlying differences in perspective rather than rhetorical statements contributes to conflict resolution in several ways. First, fostering cooperation in watershed protection efforts requires understanding stakeholder interests and values, and DEP's incentive to encourage cooperation is high. Its ability to police the innumerable individual actions that aggregate to large-scale water quality problems at the end of the pipe is limited. As one resident put it at a public hearing: "We all know, as does NYC, that it will be impossible to enforce these regulations without the help and consent of local officials, government agencies and village centers. We can't all be watched all the time. If the regulations pass as is, the battle will have been lost, but the war will have just begun." Second, the way watershed stakeholders view and value different characteristics of the watershed determines their uses of the watershed. Understanding the basis for different views and values helps anticipate the effect of human activity on watershed resources, and develop strategies to promote or prevent different activities. Third, the way different groups perceive a problem determines the way the validity they assign to tools, or inputs, for developing solutions to the problem (Dietz et al., 1989). The designation of scientific expertise, money, or public opinion as legitimate inputs then determines who participates in the development of solutions to a problem and, ultimately, whether those solutions are accepted. For example, if a conflict is defined as "political", public support may be considered a crucial resource, while

scientific expertise, data, and simulation models are more acceptable in a conflict defined as "scientific".

The New York City DEP began by defining the problem as a scientific one and addressed it with scientifically based land use regulations. Some watershed farmers and planners rejected the DEP's scientific definition, claiming the DEP did not have enough scientific justification for its regulations or land acquisition program. One county planner noted that until parties in the conflict trust each other, science is used more as a courtroom weapon by "duelling scientific experts" rather than a tool used cooperatively to find a good solution. Some local government officials see the conflict as a political challenge to local autonomy; others as an economic problem of unequally distributed costs and benefits. Some City-based stakeholders see land acquisition and regulation as an economic issue that can be resolved with adequate payment to landowners. Some landowners, however, have no interest in selling. Stories of the communities displaced as recently as 1965 to build New York City reservoirs in the Catskills support their fear that their land will be taken by condemnation. They see the issue as political, in which financial compensation is irrelevant. Farmers and other Catskill residents resent the implication that they care only about money and are not good stewards of the land. As one farmer explained simply to DEP officials on a watershed farm tour: "This farm is all I've got. Those of us who chose agriculture as a career, we're just as good stewards as the Greens; we take care of the land. I'm sure I could be selling cars or refrigerators and making more money--I'd be good at it, I like people--but I don't know as it would be so rewarding. I'd rather be producing meat and milk. The land owns us. Those of us foolish enough to work so many hours for so little money, the land owns us."

Rather than trying to recognize and resolve multiple points of view, some stakeholders still see the problem as convincing others to see their point of view. One City resident at a meeting to discuss how to increase the participation of City residents in watershed discussions said: "I have many friends upstate who are 'enlightened' but they just don't know [our issues]. The information isn't there and we have to get it there ... it's so obvious! We ought to hit the media. Let's picket them and create some news." He sees the problem then, not as trying to find common ground in the way stakeholders see the world, but to convince other stakeholders to see it his way.

Conclusion

What has become clear in the last five years, as the controversy has evolved and unfolded, is that stakeholders view and value watershed resources differently. Like the blind men asked to describe the elephant based on what they "saw" with their hands, these different views come from the different contexts within which stakeholders interact with the watershed. None of the perspectives is so much wrong as it is incomplete. It emphasizes the part of the issues with which each stakeholder has the most experience and interest. Differences in stakeholder perceptions affect the positions stakeholders take and claims they make regarding watershed resource management. What has also become clear is that any lasting watershed management solution, especially in the case where non-point source pollution prevention cannot be controlled by force, has to account for different perspectives. Expecting, recognizing and seeking to understand the basis for differing views is the first step toward sustainable watershed management.

Acknowledgements

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A Multiple-Watershed-Wide Modeling Approach of Dissolved Oxygen in New York Harbor

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Dissolved oxygen conditions in New York Harbor estuary have improved considerably over the past 50 years as a result of improvements in wastewater treatment by the City of New York and other jurisdictions that discharge to the harbor. Nevertheless, dissolved oxygen in specific areas within the harbor proper and in major water bodies such as western Long Island Sound, Raritan Bay and Jamaica Bay contiguous to the harbor continue to be depressed below desired levels. Much of the remaining depression is caused by eutrophic conditions triggered by nutrient, especially nitrogen, discharges to the harbor estuary. Nutrients and BOD from organic carbon enter the harbor from a variety of sources: more than 100 sewage treatment plants, 700 combined sewer overflows, thousands of stormwater discharges, 11 major tributary rivers including the Hudson, Raritan and Connecticut Rivers, coastal runoff and atmospheric disposition. The sources are located in three states surrounding the New York City Metropolitan area: New York, New Jersey and Connecticut.

One mission of the New York City Department of Environmental Protection (DEP) is to support the continual improvement of water quality conditions in New York Harbor. As part of a major upgrade of the 350 MGD Newtown Creek Water Pollution Control Plant, DEP is developing a major Water Quality Plan for the harbor. As it is known from previous mathematical water quality modeling work that water quality in the New York Harbor estuary is affected by thousands of discharges from three states as discussed above, the approach for development of the Water Quality Plan is necessarily watershed-wide covering multiple watersheds. The technology used in the study process includes application of mathematical models to establish quantitative cause and effect relationships among the thousands of pollutant inputs in the tributary watersheds and dissolved oxygen conditions in the harbor estuary.

The Dissolved Oxygen Issue

The major impetus for the Water Quality Plan is low dissolved oxygen levels in the East River and western Long Island Sound. The East River is classified for a minimum dissolved oxygen standard of 4.0 mg/L. During the summer months, there is a persistent non-attainment of this standard in the bottom waters. Major, but by no means only, causes for the oxygen depletion in the East River are the carbon (BOD) discharges from six East River sewage treatment plants.

The causes of low dissolved oxygen levels in western Long Island Sound are considerably more complex. Recently, the Long Island Sound Study (LISS) of the National Estuary Program funded the development of a mathematical model of Long Island Sound including an extensive field program to assess water quality conditions and the relationships between loadings and low

dissolved oxygen levels.

In natural systems, which receive little or no anthropogenic inputs, hypoxia may occur in the summer months if strong density-induced stratification occurs in the water column. The stratification reduces mixing between surface and bottom waters and restricts the transfer of oxygenated surface waters to the oxygen-deficient bottom waters. However, the additional input of anthropogenic nutrients into Long Island Sound exacerbates the condition of hypoxia. This occurs because the addition of nitrogen and phosphorus to the system stimulates phytoplankton growth (eutrophication), which results in a greater sink of dissolved oxygen in the lower layers of the water column.

Nature of the Mathematical Water Quality Model

The mathematical model of water quality in the study area is a representation of the principal components of the environment that influence the dissolved oxygen balance. The eutrophication-based model incorporates the input of point and nonpoint sources, estuarine circulation and mixing, the principal mechanisms of phytoplankton interactions with light, water temperature, and nutrients, and the behavior of the various nutrient forms themselves. The model also incorporates the effects of atmospheric reaeration, photosynthetic oxygen production, algal respiration, the oxidation of organic carbon and sediment oxygen demand (SOD).

The water quality model is linked to a hydrodynamic model of the system (HydroQual, 1995). The hydrodynamic model feeds the water quality model cell depths, velocities and mixing coefficients averaged over one hour intervals. Both the hydrodynamic and water quality models are implemented on a shoreline fitted, orthogonal, curvilinear coordinate system.

Model Development

The planning process is proceeding in two phases: construction of a New York Harbor Eutrophication Model (HEM) for screening of planning alternatives, and development of a System-Wide Eutrophication Model (SWEM) for detailed evaluation of management options. Schematics of the HEM and SWEM model segmentation are shown on Figures 1 and 2, respectively. Each model has ten vertical layers for a total of 7400 grid elements in HEM and 10,000 grid elements in SWEM. The HEM model encompasses the tidal portions of the Hudson, Hackensack, Passaic, and Raritan rivers. In SWEM there are additionally seven Connecticut tributaries for a total of eleven watersheds. A major reason for the SWEM model development is to move the boundaries of the model far enough away from internal pollutant loadings so that they do not have an effect on model projections. Each model is comprised of two components: hydrodynamic and water quality submodels. All models are state-of-the-art, three dimensional time-varying computational tools. The water quality submodel computes more than 25 water quality variables at 15 minute intervals for 12 month long simulations. The models are executed on a mini-supercomputer. The models are being calibrated with existing year long data from the 1988/89 period and are being validated with data collected from more than 100 sampling stations in the tri-state region during 1995.

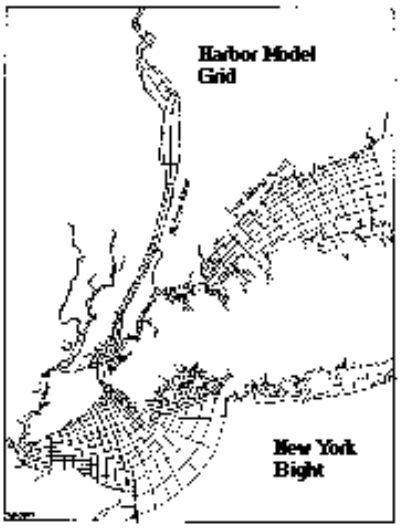

Figure 1. HEM Model Domain.

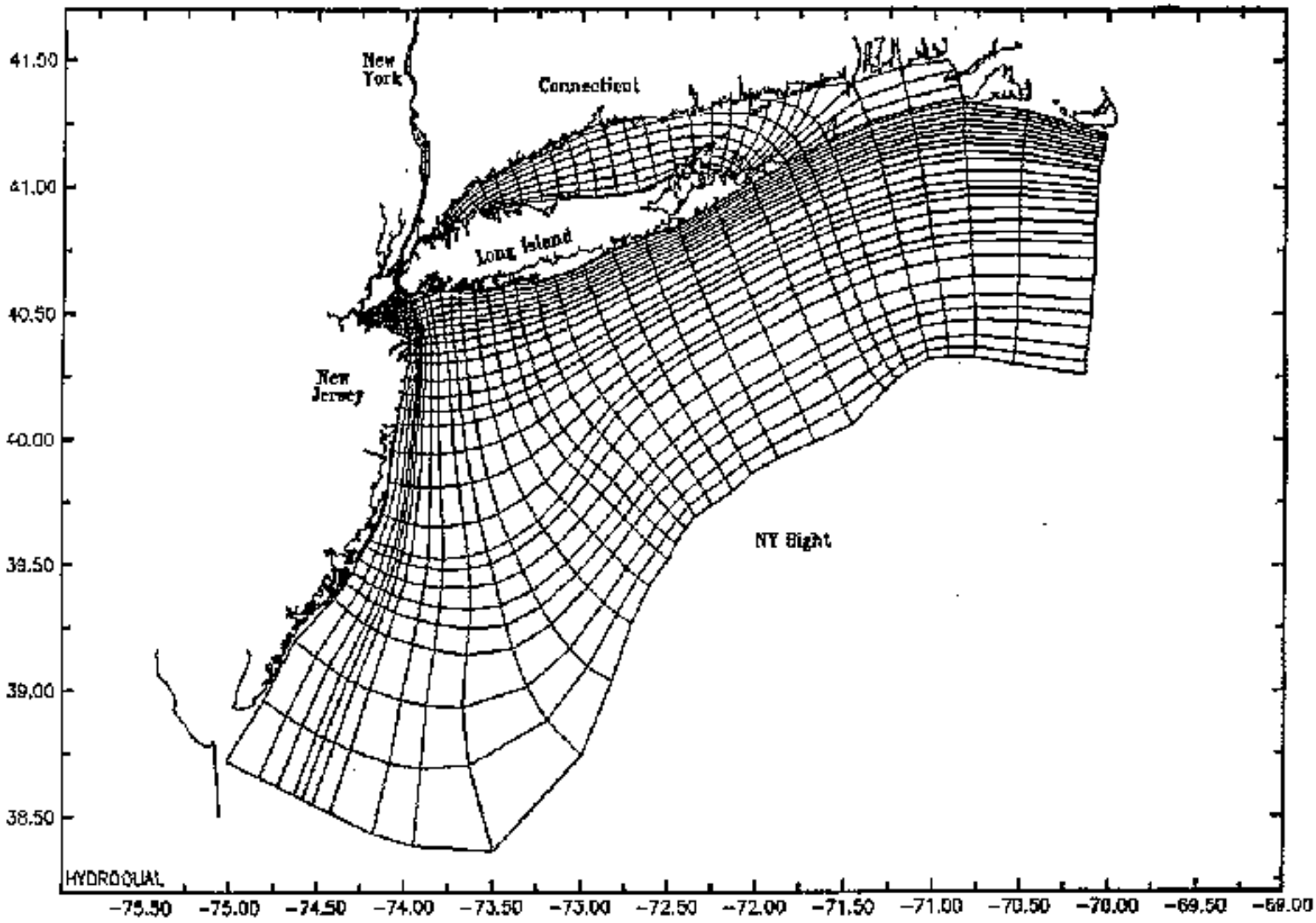

Figure 2. SWEM Model Domain.

Loading information is generally developed from Discharge Monitoring Records and specific field measurements collected for these projects. There are twenty-five state variables and for some of these variables, the form of the variable (dissolved and particulate) must be specified. Runoff loadings (CSO and stormwater) are generally generated from SWMM models developed for other DEP planning projects and from rainfall-runoff models developed as part of other area-wide planning studies.

A summary of the 1988/89 total nitrogen, total phosphorus, and total organic carbon loads to the HEM domain are presented on Figure 3. The figure presents six loading categories; these include sewage treatment plants (STPs), industry, combined sewer overflows (CSO), stormwater (SW), tributaries, and atmospheric loadings. The total load is also shown. Each bar graph is further segregated by regional discharges. These regions include New York City, other New York State (without NYC), New Jersey, and Connecticut. The NYC STP discharges account for about one-third of the total load. The NJ STP discharges are also a significant component of the total load as are tributary inputs, most of which are from the Hudson River.

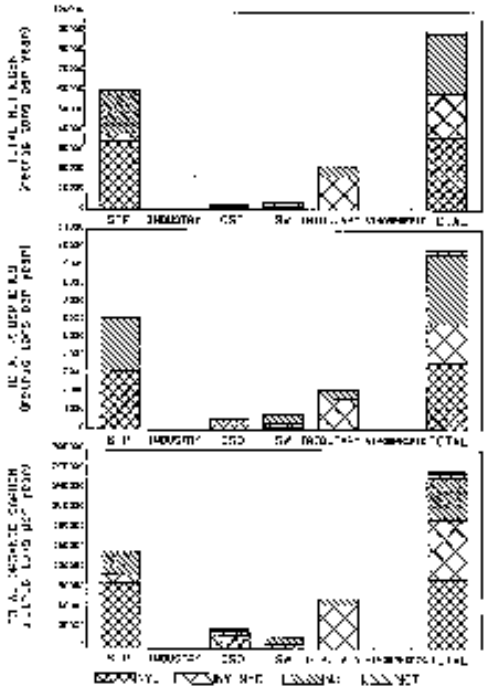

Figure 3. Summary of 1988/89 Loadings.

The loads calculated for the 1988/89 calibration period and the 1994/95 verification period are inputs to the HEM/SWEM water quality models. Model output is then compared with observed water quality data. An example of model output comparisons to the observed data is shown on Figure 4. The figure shows dissolved oxygen responses at six location in New York Harbor. The top dashed line is the saturation value for dissolved oxygen. The other two lines are the calculated responses in the surface and bottom layers of the model. The 1988/89 observed data are represented by triangles while other historical data are represented by circles. The model-data comparisons are on a temporal basis with the model results showing monthly mean concentrations. The model-data comparisons are in good agreement with the model reproducing a wide variety of physical, chemical and biological conditions throughout the harbor. For example, at station 3 (Upper East River - LIS), both the model and data indicate a strong vertical stratification with respect to dissolved oxygen. In contrast, at station 4 (East River - 42nd Street) both the model and data are well mixed between the surface and bottom layers.

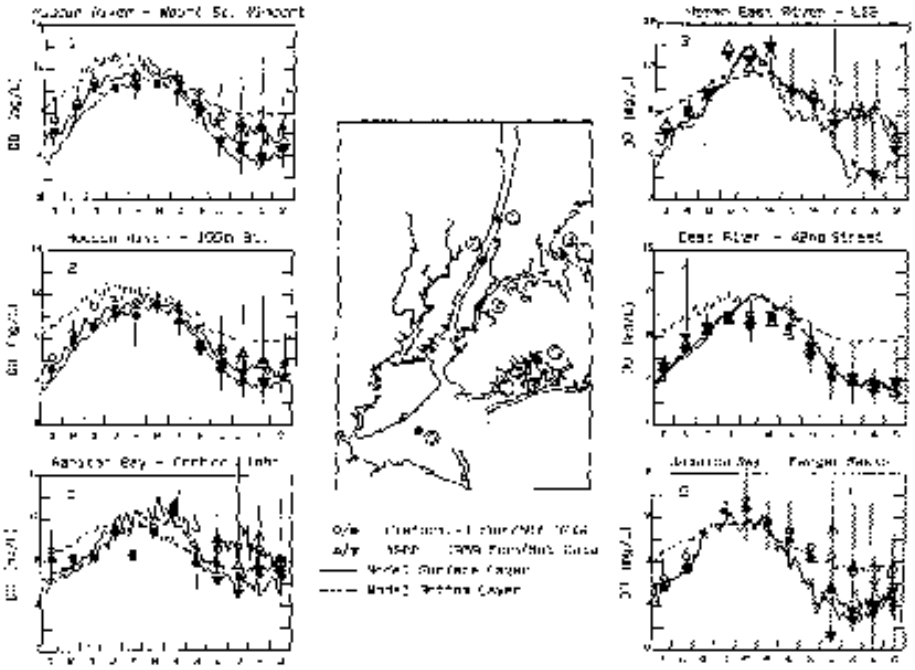

Figure 4. HEM 1988/89 Calibration.

Model Application

The calibrated HEM model will first be used to develop component responses for the dissolved oxygen distribution. A baseline case has been developed based on 1993/94 loadings as a representation of existing conditions. The component responses will demonstrate the effects of various categories of pollutant inputs (treatment plants, CSOs, stormwater, tributaries, etc.) on water quality and dissolved oxygen conditions at various locations in New York Harbor. These component analyses will guide the development of approximately twenty engineering alternatives. In a broad sense, these alternatives will include treatment, outfall re-location, and artificial aeration. The HEM model will be used to screen these alternatives.

The calibrated/verified SWEM model will be used for final evaluation of alternatives. As mentioned above, the boundaries of the SWEM model are sufficiently distant from the primary study area so that they will not be a factor in the analyses of alternatives, particularly those alternatives that involve outfall re-location or tidal circulation modification by tide gates.

In summary, state-of-the-art hydrodynamic and water quality models are being developed to evaluate engineering alternatives that may have water quality impacts on an area-wide basis. In this study, the engineering alternatives being considered is focused on East River discharges. However, the impacts from other entities, (i.e., other New York discharges, Connecticut discharges, New Jersey discharges) will also be quantified. The HEM model, with a limited domain, is used only to screen alternatives. The SWEM model, with an extensive spatial domain, will be used for final evaluation of East River alternatives and can also be used by managers for area-wide planning and/or wasteload allocation on a multiple-watershed basis.

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Watershed Nonpoint Assessment and Nutrient Loading Using the Geographic Information System-Based MANAGE Method

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Nutrient Loading as a Tool for Local Nonpoint Management

Nutrient loading models for watershed-based nonpoint source management are numerous and well documented. They range from simple, desk-top techniques that require only minimal information about a watershed to highly complex simulations of pollutant inputs and pathways based on extensive field monitoring. With so many methods available, why is it so rare to find them actually used to support local land use decisions? Often, they are either too complex for planning staff to use or costly field monitoring is necessary to calibrate the model. When a model is easy to apply, it is commonly applicable only to certain types of watersheds of soil conditions, or the results are so generalized as to be of little value.

Municipal officials have the opportunity to prevent nonpoint pollution through their land use decisions at both the planning and project review level. Yet, without a practical method to quantify nonpoint impacts and estimate the potential water quality impact of management practices, municipalities face serious obstacles to effective control of nonpoint pollution. For example:

- The relative nonpoint pollutant contribution from various watershed land uses is often uncertain,

which discourages communities from setting control priorities.

- The level of control needed is difficult to identify. Local officials must be convinced that nonpoint inputs are affecting or have the potential to seriously impair valuable water resources before adopting more stringent controls. The effectiveness of nonpoint management practices is not well understood. Local officials need information on the relative benefits of management options to select appropriate controls, to generate public support for adoption of controls, and to establish defensible land use regulations.

- Tight budgets limit local capability to adopt, monitor and maintain nonpoint management practices. When the price tag for sewers or stormwater improvements is high, municipalities are likely to gain public support for new pollution control projects only when the cost of inaction exceeds the control cost.

MANAGE: A Method for Assessment, Nutrient-loading, And Geographic Evaluation of Nonpoint Pollution

The University of Rhode Island Cooperative Extension, with support from the Cooperative State Research Education and Extension Service (CSREES), is developing a practical method that municipalities and state resource managers can use to manage nonpoint pollution in watersheds of freshwater lakes, coastal embayments, and groundwater aquifers. The MANAGE method is a GIS-based watershed management tool that will (1) spatially identify nonpoint source pollutant "hot spots" and (2) estimate the loading of phosphorus and nitrogen to surface water and the loading of nitrogen to groundwater reservoirs. Both components take advantage of the extensive Rhode Island Geographic Information System (RIGIS) database_one of the most comprehensive compiled for a large area.

MANAGE is intended to be used by land use planners and resource managers as one of many tools available to aid in the process of water resources protection. It has been developed specifically for use in Rhode Island and the New England region to assess the effects of current land use, future development alternatives, and pollution management practices on valuable water resources. Because variables and assumptions are easily modified, MANAGE can be used to study the effects of many different scenarios. By evaluating both land use and nonpoint control options, the MANAGE method can support adoption of land use policies and nonpoint controls needed to effectively reduce nonpoint inputs to sensitive water resources. Our objective in developing this model is to provide local decision makers with a watershed management tool that can be used to accomplish the following:

- Spatially identify pollution "hot spots" having a high potential to generate nonpoint sources of pollution within a watershed.

- Calculate nitrogen and phosphorus loading to surface waters, and nitrogen loading to groundwater under present land use.

- Compare the change in pollution potential and nutrient loading with build-out under present zoning or other development scenario.

- Compare nutrient inputs with critical freshwater eutrophication levels and drinking water quality standards.

- Estimate the reduction in nutrient loading with implementation of stormwater and wastewater management practices.

- Increase public awareness of nonpoint pollution sources and management solutions through use of model output products.

Nutrient Loading Component of MANAGE

The date required to run the nutrient-loading model is easily obtained from the Rhode Island Geographic Information Systems (RIGIS), maintained on the ARC/INFO GIS software. The LAND USE, SOILS, SEWER, and HYDRO coverages provide the minimum data necessary as input for the model. The model identifies areas with a high potential to contribute nonpoint pollutants using: 1) watershed land use; 2) soil suitability for on-site wastewater disposal based on soil hydrologic group; and 3) riparian land use.

Field monitoring data is not required to conduct the nutrient loading analysis. Like other mass balance models that are not calibrated with watershed-specific data, the nutrient concentrations calculated for the groundwater recharge percolate and the inland surface waters should not be expected to correspond directly with groundwater or surface water quality samples. Water reaching municipal wells represents a mix of various travel times and sources. Rather, the nutrient concentrations calculated by the model should be viewed as one of many indicators of watershed health. They are most useful in determining relative pollutant loadings under various land uses and management options.

Method

Our approach in developing the MANAGE method has been to review nutrient loading methods successfully applied in other areas and compare commonly accepted pollutant loading factors with results of current research conducted by URI researchers and others. Many other models currently in use were examined to determine the best combination of features appropriate to local conditions The processes being modeled are complex and time-dependent, and this model attempts to simplify these processes while maintaining integrity and user-friendliness.

The nutrient loading component of MANAGE differs significantly from other mass balance models currently used in the Northeast (Schuler, 1987; US EPA, 1990; Weiskel and Howes, 1991). Unlike existing models, the MANAGE nutrient loading method is applicable to both surface waters and groundwaters; it calculates both nitrogen and phosphorus inputs; it examines surface runoff and

infiltration; and it addresses the influence of soil type and riparian areas on pollution movement and attenuation. It addition, it factors in the effect of stormwater and wastewater management improvements and takes advantage of GIS to spatially identify and illustrate pollution problem areas.

Nutrient Loading Features

Some of the unique features in this model are summarized below:

- The Rhode Island Geographic Information Systems (RIGIS) data base is used to obtain land use types and development density, soils, sewering and public utilities data. The RIGIS data base was developed from many sources including (1:24,000) USGS Topographic maps and (1:15,840) USDA Rhode Island Soil Survey maps.

  - Surface runoff and groundwater infiltration rates are calculated based on both land use and hydrologic soil group. The hydrologic soil group is an indicator of the potential for rainwater to infiltrate the soil surface rather than generating surface runoff.

  - Pollutant loading factors for surface runoff and infiltration are based on results of research conducted in Rhode Island and an extensive literature review.

  - Soils with restrictive layers are identified and highlighted as causes of septic system malfunction. estimated based on the development density, and on the potential for these systems to The nutrient load contribution from malfunctioning septic systems to surface waters is discharge inadequately treated effluent as a function of soil features.

  - The effect of riparian areas (land area within 100 ft. of surface water shorelines) is factored in the estimation of septic system effluent contributions to surface waters.

Analytical Functions

The model is divided into two main analytical functions, where the receiving water is:

  - surface water_a surface watershed can be studied as a whole, or by subwatershed, running the model for each subwatershed.

  - groundwater_a groundwater contributing area can be a groundwater drainage area, groundwater reservoir, or well head protection area (WHPA).

Surface waters and groundwater are treated independently of one another since a surface watershed can be different from the area contributing to groundwater. If a surface watershed is being studied, the area for groundwater data entry can be left blank, and vice-versa. We are currently developing the portion of

the model which will estimate nutrient loading to a coastal embayment by using the results of both the surface and groundwater analyses.

Existing Features

To evaluate the status of either a surface watershed or groundwater contributing area, the nutrient loading component of the MANAGE method has been developed in spreadsheet format. Existing functions are summarized below:

- Estimates the average annual nitrogen and phosphorus loading to surface waters (reservoir or lake) in lb P/yr and lb N/yr, and the average annual volume of surface runoff contributing to the receiving water. An additional subcomponent of the model will be added to estimate the response of a freshwater pond or lake to the phosphorus loading in the form of an average annual phosphorus concentration (ug/l) and a likely trophic state. This is not attempted for coastal embayments because a reasonable and accurate method has not yet been developed. Loading estimates provided by the model could be used to evaluate eutrophication in coastal embayments when a method is available.

- Estimates the average annual nitrogen loading (lb N/yr) and average annual recharge (Mgal/yr) to a groundwater reservoir.

- Estimates the average annual concentration of nitrogen in the percolating recharge water (mg/l). This has been used as an indicator of the well-water quality derived from the aquifer.

- Allows the user to easily modify land use to evaluate the relative change in nutrient loading with various land development alternatives.

Features Currently in Development

- Estimates the total average annual nitrogen loading (lb N/yr) to a coastal embayment from both surface and groundwater inputs, if requested.

- Produces a summary of the status of the watershed or groundwater contributing area, identifying high-risk land uses, management practices, and other watershed characteristics which can degrade water quality.

- Identifies best-management practices and land uses which help protect the receiving water from pollutant loading. Loading results are interpreted, and suggestions are made regarding development and management issues.

- Identifies locations within the watershed or groundwater contributing area with a high potential

for pollution.

The average annual loads are reported in lb/yr and the concentrations are reported in mg/l for nitrogen and ug/l for phosphorus. The calculated average annual concentrations are indicators of the effects of land use on water quality, and cannot be compared to any single sampling data point. Rather, the strength of the model is in comparing and assessing the effects of various land use and management scenarios under consideration.

Future Direction

The MANAGE method is currently being tested in the Hunt-Potowomut coastal watershed and Hunt River aquifer, North Kingstown, Rhode Island. Following completion of the draft method, scheduled for 1996, a user-friendly interface using the ArvView GIS software is planned. URI Cooperative Extension will train local officials in use of the model and provide technical assistance in GIS database development to promote use of the method in priority watersheds. User manuals and workshops will be developed and conducted through existing URI Cooperative Extension outreach programs to municipalities.

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Indianapolis Uses New Radar Technology to Refine Hyetographs for CSO Model and SSES Studies

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Introduction

Indianapolis is one of several Cities that has become increasingly aware of the importance of accurate rainfall measurement. Rainfall is the engine that drives all CSO, Storm Water Management and Sanitary Sewer wet weather programs. Each of these programs require us to characterize a catchment's response to a rain event with a fair amount of accuracy, but seldom do we use the same degree of accuracy to measure rainfall. For example, the current national CSO guidelines establish an overflow frequency of four (4) times per year, yet there is no recognition of the geographic and temporal variation of the rainfall causing the overflow. Also the Nation's ongoing SSO dialogue discusses such issues as an "Affirmative Defense" for collection system operators. Any Municipal defense or Regulatory enforcement will most likely revolve around an accurate understanding of rainfall.

In the Fall of 1994, Indianapolis became the first U.S. city to employ the French technology, CALAMAR, to measure rainfall for its Lick Creek SSES project. CALAMAR is a French acronym for Calcul de LAMes d'eau l'Aide du Radar or Calculating Rainfall with the Aid of Radar. CALAMAR uses a local rain gauge network to calibrate the National Weather Service NEXRAD (NEXt generation RADar) radar images to obtain geographically precise rainfall measurements. The City's long range plan is to utilize a network of 25 rain gauges to calibrate the NEXRAD images over an area of 400 mi2.

The Lick Creek SSES project was used as the first test of CALAMAR's accuracy and effectiveness. The Lick Creek study area is around 12 mi2. in area and is located on the City's south side. Five (5) temporary gauges were installed both to provide rain gauge information for the SSES study and for calibrating the CALAMAR images. The study period was from September through November 1994.

Methodology

CALAMAR uses three sets of data: NEXRAD radar images of reflectivity, 5-minute rain gauge data and a geographic database of the catchment areas. CALAMAR performs three separate transformations of these data to obtain geographically correct absolute rainfall rates.

Step 1-Selecting the Proper Tilt

NEXRAD uses up to 14 radar tilts (angles of inclination) to develop an entire radar "picture" during periods of precipitation. The lowest tilt is 0.5 degrees of elevation and the highest tilt is around 18 degrees. The NEXRAD computer combines all tilts to characterize an entire "volume" around a radar site. Unless the terrain is unusual or there are other types of obstruction in the area, CALAMAR usually uses only the lowest tilt because it most closely represents precipitation reaching the ground. The NEXRAD site is near the Indianapolis International Airport approximately eight (8) miles southwest of the city and the radar at the lowest tilt intercepts the tallest buildings in the downtown. As it turns out, there is significant ground clutter throughout the Indianapolis area and the second radar tilt (1.5 degrees) is used within a 20-mile radius of the radar. Beyond 20 miles, the first tilt is used, except for the area masked by the tall downtown buildings.

Step 2-Advection

Advection is a weather term referring to the transport of atmospheric properties by the wind. Radar images, on their own, produce a series of 10 images per hour. These images alone cannot be used to measure rainfall during fast moving storms, because of the gaps between images. CALAMAR uses pattern recognition to determine that a rain cell moved from one point to the second point at a certain velocity and at a certain intensity. These advected or vectored images are then calibrated with rain gauges.

Step 3-Calibration

The advected radar reflectivity images provide relative rainfall intensity values for each km2 and the rain gauges provide ground truthing as the rain cell passes overhead. Although NEXRAD provides excellent geographic location for each rain cell, the estimated rainfall intensities based on reflectivity can be off by as much as two to eight times. The NEXRAD operators try to adjust the reflectivity-to-intensity relationship, but the relationship varies with the type of storm, the size of the rain drops, wind speed etc. Because the relationship is so variable, CALAMAR uses the ground truth from the 25 rain gauges to

calibrate each storm. As a general rule, NEXRAD comes closer to accurately measuring rainfall during wide spread, steady, low intensity rains and is most inaccurate during intense localized storms.

Results

Intense frontal storms typically are responsible for the rain events that are of greatest interest to municipal hydrologists. They usually produce the highest rainfall rates and have the greatest variation in rainfall distribution. An example of such a frontal storm occurred on the evening of 27 November. Figure 1 shows the storm accumulation on the Lick Creek study area. The pixel size is 1 Km. x 1 Km.

The rain cells during this storm were around 2 to 4 kilometers in diameter. The heaviest rainfall accumulation shown in Figure 1 (Approximately 37 mm.) varies from 2 to 6 kilometers in width. It is easy to see that rain gauge spacing of 9 to 16 km. (5 to 10 miles) could allow these major cells to "sneak" through and cause the greatest amount of rainfall to be undetected. These observations lead to the conclusion that rain gauge networks ought to be no more than 3 km. apart. In fact, this technology has allowed French users to observe that approximately 80% of rain from significant storms come from cells 6 km. or less in width

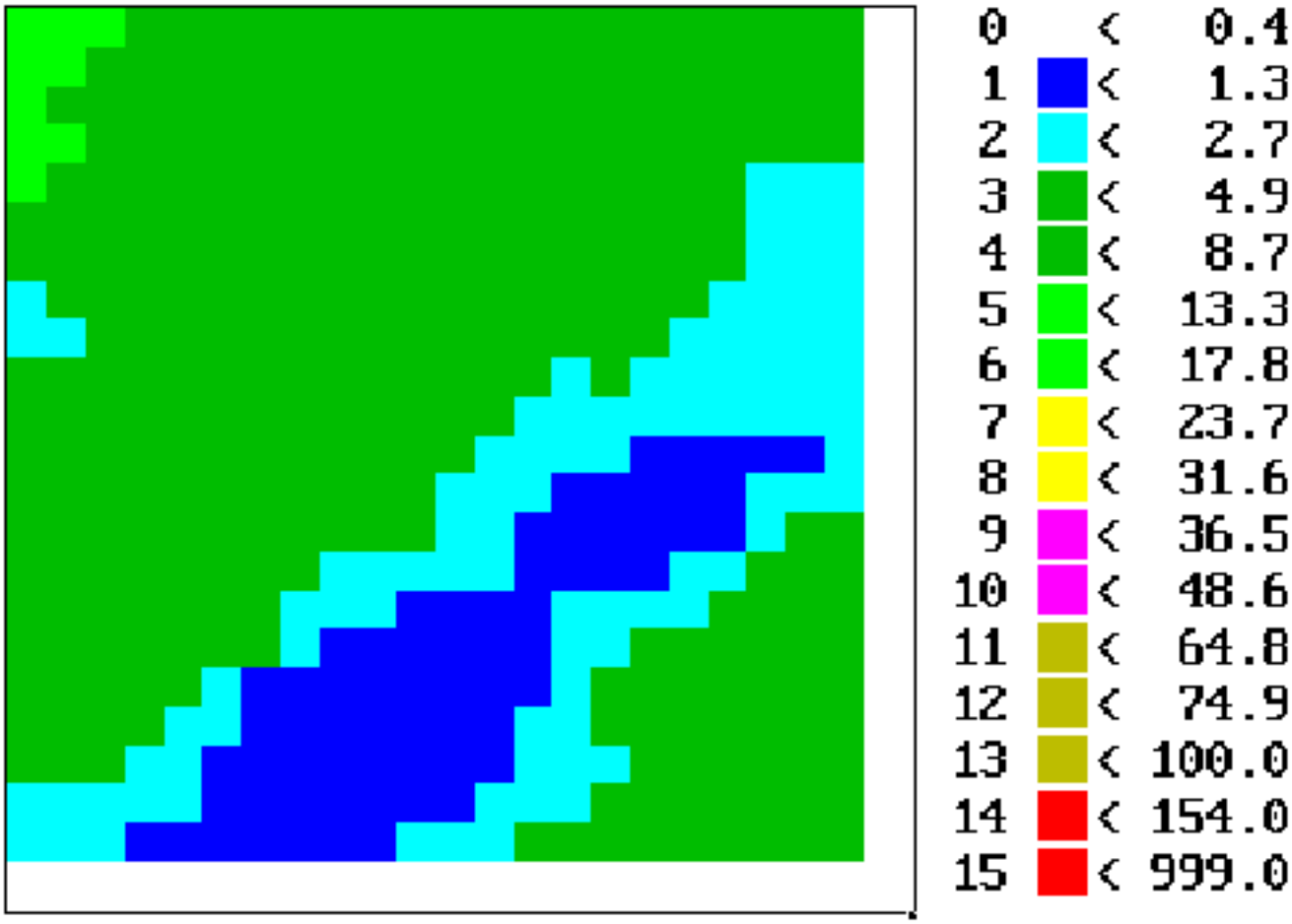

Figure 1. Accumulated Rainfall on Lick Creek Area (22 Km x 22 Km).

The Product

CALAMAR integrates the calibrated rainfall over each catchment area that has been digitized. Outputs include a hyetograph for each catchment area and a rainfall total for each catchment. Table 1 lists the accumulated rainfall for each catchment in the Lick Creek Study Area for the 27-28 November 1994 storm.

Conclusions

1. CALAMAR offers rainfall resolution superior to traditionally-spaced rain gauge network by a factor of 20 to 30.

2. CALAMAR can provide this superior knowledge at a fraction of the cost of a rain gauge network with similar resolution.

3. CALAMAR's ability to generate hyetographs for individual catchments can allow for more accurate calibration of hydraulic models.

4. Indianapolis will incorporate CALAMAR as a key feature in its wet weather programs, including CSO compliance, I/I removal and storm water management.

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Making the Most of State and Tribal Water Quality Assessment Data: New Tools and Approaches

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The Development of the Waterbody System Database

In 1987, EPA released Surface Water Monitoring: A Framework for Change (U.S. EPA, 1987). Among this report's recommendations was the development of a water quality tracking system to assist States in the preparation of reports required under Clean Water Act section 305(b). EPA uses state 305(b) reports to develop biennial National Water Quality Inventory Reports to Congress. The 1987 Framework document led to the creation of an assessment database called the EPA Waterbody System (WBS) as well as to other initiatives to improve the consistency of information presented in the National Inventory Reports. EPA worked closely with the states in developing WBS to ensure that user needs were met.

Basic Concepts and Data Elements in the Waterbody System

To assemble an assessment database at the national level, EPA relies on each state to develop its own WBS data base. States have the flexibility to define waterbodies to best serve their management needs. For rivers and streams, common approaches include:

- Delineate stretches between tributaries as separate waterbodies.
- Include all stream traces in a small watershed as a waterbody.
- Delineate larger streams in a linear fashion and tributary systems as small watershed

waterbodies_a hybrid approach.

Once a waterbody is delineated, WBS can manage a wide range of assessment information for that waterbody. The main data elements focus on attainment of designated uses and on causes and sources of impairment (U.S. EPA, 1994). Designated uses typically include aquatic life support (fishing), body contact recreation (swimming), and drinking water supply. Causes include physical, chemical, and biological stressors ranging from nutrients to toxicants to habitat modification. Sources include point source discharges and nonpoint source runoff from many urban or rural land use activities. For example, a WBS user could access the following data about a particular waterbody:

Waterbody ST-001, Jones Creek, is 5.1 miles long and located in USGS Cataloging Unit (CU) 01010102 and the Big River Basin. Jones Creek fully supports drinking water and swimming uses; 4.5 miles do not support aquatic life use. Causes of impairment include metals (1.5 miles) and sediment and habitat modification (4.5 miles). Sources include row-crop agriculture and urban runoff (4.5 miles). This assessment is based on chemical monitoring for conventional pollutants and toxicants and biological monitoring for macroinvertebrates and fish.

Availability of Waterbody- and Watershed-level Data

During 1995, EPA and RTI assembled all available State WBS files, validated the data, and created a database for as much of the country as possible. A primary objective was to ensure that most or all waterbodies were georeferenced to their appropriate USGS Cataloging Units (CUs). By the end of 1995, WBS files containing information from the 1994 305(b) reporting cycle were available for 51 states, territories, and interstate river basin commissions. More than half of these entities use WBS and the remainder use in-house systems that are compatible with WBS. The national WBS files contain approximately 50,000 waterbodies in nearly 2,000 CUs. The 1996 305(b) cycle should result in a similar high level of availability of assessment data.

Georeferencing Waterbodies to the EPA Reach File

As noted, WBS contains data elements to identify each waterbody's basin or watershed, such as standard USGS CUs, USDA small basins, and State-defined small watersheds. To further pinpoint the location of waterbodies, EPA encourages States to georeference their waterbodies to unique hydrologic segments contained in the national EPA Reach File Version 3 (RF3; U.S. EPA, 1995). RF3 is based on line traces from the USGS 1:100,000-scale Digital Line Graphs used to produce printed topographic maps and contains a consistent hydrological network organized according to the USGS 8-digit CUs. EPA provides software tools and technical support for this georeferencing, or reach indexing, process. Reach indexing makes possible detailed map displays of WBS information and the overlay of WBS data with other coverages. Figure 1 shows the status of reach indexing efforts as of February 1996.

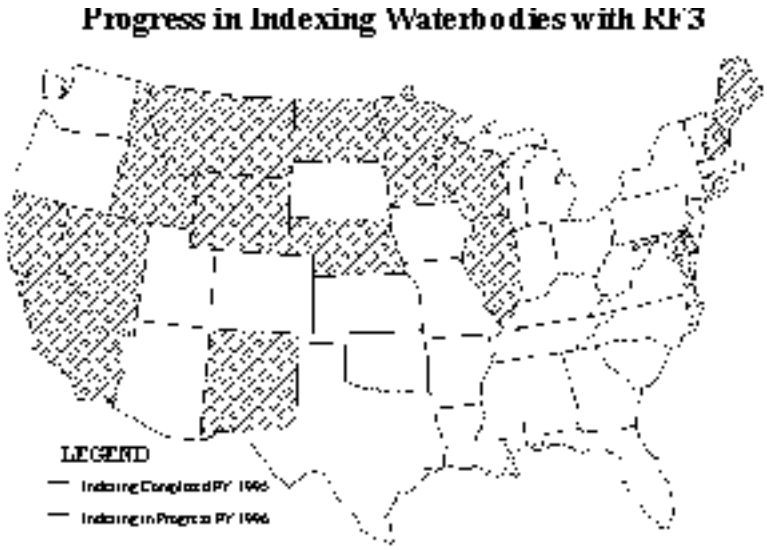

Figure 1. Status of indexing waterbodies with RF3 (February 1996).

WBS information can be used to identify the geographic distribution of certain causes or sources. For instance, NOAA and EPA have used WBS data to identify pollution causes and sources in estuarine and coastal waterbodies and in river waterbodies in coastal counties as part of the process of enhancing State coastal zone nonpoint control programs under the 1990 Coastal Zone Act Reauthorization Amendments. WBS data have also been used to estimate the frequency of pollution stressors related to habitat loss as compared to the more traditional types of chemical-specific pollutants. Increasingly, however, applications of WBS information will involve processing the data to create watershed-level indicators. And where waterbodies are indexed to RF3, fine-scale GIS spatial analysis is possible.

Applications for WBS Data Summarized by Cataloging Unit

EPA is coordinating with the USDA to enhance the water quality-oriented components of the 1997 USDA National Resource Inventory report. As part of this cooperative effort, RTI and Tetra Tech are processing WBS information to support EPA in developing indicators of the extent of agricultural pollutant impacts within CUs. The USDA is making use of USGS CUs as the framework for summarizing the effectiveness of Farm Bill programs in reducing soil erosion and related agricultural pollution stressors. For instance, for each CU, the ratio of the number of waterbodies with agricultural impacts divided by the total number of assessed waterbodies is easily calculated. Where agricultural impacts are widespread, this ratio may be close to 100 percent.

Where agricultural problems are less prevalent or constitute limited hotspots, the ratio will be much lower. A draft prototype example is shown for Ohio in Figure 2, in which ratio indicators at the CU level are grouped into high, medium, and low categories. Similar indicators could then be developed for the entire country.

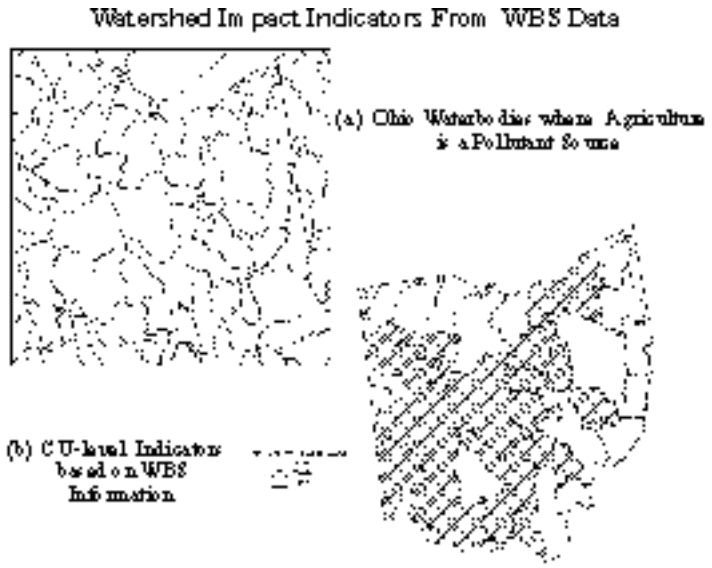

Figure 2. Prototype example of developing watershed-level indicators from WBS data.

GIS Applications for RF3-Indexed Assessment Data

For those states that index their waterbodies with RF3, GIS technology makes it easy to develop detailed maps of WBS assessment information. Figure 3 shows an example of these new tools for producing interactive visualizations tied to a water quality data base. This graphic is based on indexed waterbodies in a CU on the James River in Virginia. WBS data are queried to display a small watershed area showing impacts from point sources of pollution. Steady improvements in GIS software for both workstation and PC platforms will eventually put these new spatial data base tools in the hands of all State water quality agencies. RF3 indexing provides a strong foundation for water resource-oriented GIS work. As illustrated in Figure 1, by the end of 1996, waterbodies in at least half the country should be RF3-indexed.

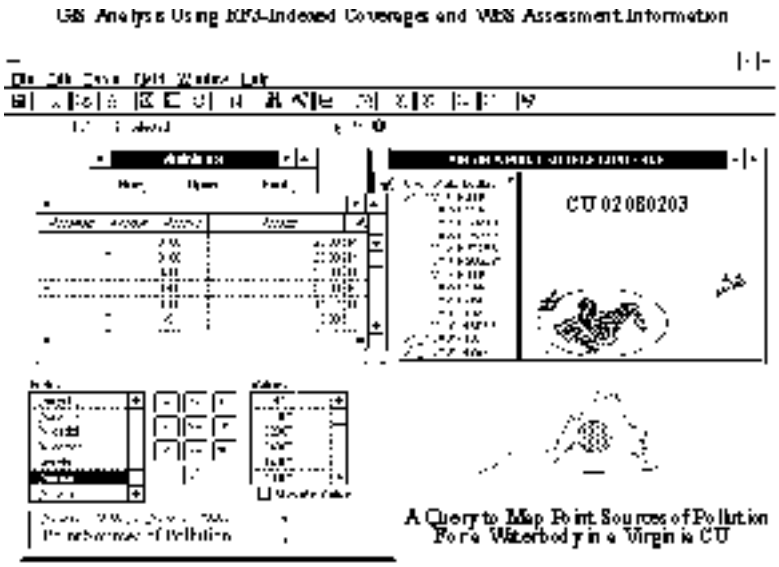

Figure 3. Mapping WBS information with GIS tools using indexed coverages.

Once a waterbody coverage is available, assessment information can be combined with other coverages to perform spatial analyses for watershed or basin management plans and for evaluating the progress in active watershed projects. Our work for North Carolina's Tar-Pamlico Basin has shown the value of overlay analysis using indexed waterbody assessment data and land cover information. The State requested a series of GIS maps of small watersheds in the Piedmont portion of the basin to distribute to field staff. These maps suggest that most extensive designated use impairments cluster in the headwater reaches where agricultural land uses and habitat modifications within stream buffer zones are prevalent.

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Impacts of Upland Land Use on Runoff. "A Global Perspective."

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Introduction

The 1993 flood on the Upper Mississippi and Missouri River Basins and the economic and social consequences in its aftermath have focussed considerable attention on existing policies and programs that have led to current land use in both the uplands and floodplains of these watersheds. The U.S. Army Corps of Engineers (COE) was tasked by Congress to conduct a comprehensive, system-wide evaluation of the basin to assess flood control and floodplain management in the flooded areas along with a multitude of other objectives including reviewing current land use and its effects on runoff. "The Floodplain Management Assessment of the Upper Mississippi and Missouri Rivers and Tributaries" (FPMA) summarizes the evaluation process, sources of information available for use and general conclusions or concerns reached by the authors on the effect of upland land use on the flood prone land located along the Mississippi and Missouri Rivers that were damaged by the 1993 flood.

The conclusions contained in the FPMA report that the existing federal reservoirs stored more than 25 million acre feet (ac-ft) of runoff and United States Department of Agriculture (USDA) assisted ponds, reservoirs and erosion control practices stored over 2 million ac-ft of runoff during the 1993 flood event. Other non-structural measures that exist in part due to USDA and other federal, state or local initiatives along with existing natural storage stored significantly more water than the structural measures mentioned above due to the vast areas involved. However, the non-structural measures and natural

storage in the basin which are effected by current land use were less effective during the 1993 flood at reducing mainstem flooding due to the saturated antecedent conditions that existed when the intense rains fell on the basins hardest hit in 1993.

Land Use Impacts on Runoff

The impacts land use has on runoff is the subject of countless studies. At times the results of these studies have been mis-interpreted or extrapolated, leading to erroneous or distorted views on how changes in land use policies can change damages associated with flooding. Land use can directly effect the amount of runoff from the land and sometimes the peak rate of runoff. Several USDA programs encourage land treatments that increase the soil infiltration rates and the soil moisture retention capacity thus reducing the amount of runoff. Other programs encourage wetland protection and restoration and reducing the acres of intensively tilled land. The installation of other land conservation measures like terraces, waterways, farm ponds, and sediment basins also store water while reducing erosion and sediment damage. Storing more water in the upland areas either above ground or in the soil profile will normally result in less runoff to contribute to flooding downstream. Other land uses like urbanization, intensive agricultural practices, removal of natural vegetation, and ditching of natural depressional areas alter the natural ability of the landscape to retain and store water thus increasing the volume of runoff.

The agricultural programs that have the largest potential for impacting flooding are the Food Security Act of 1985 (FSA) and the Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA). These acts impose restrictions on persons who participate in certain USDA programs and who plant agricultural commodities on highly erodible lands or converted wetlands. The erosion provisions of the FSA and FACTA farm bills relate directly to surface water runoff. Practices such as residue management and reduced tillage increase infiltration of water into the soil and reduce the amount of surface water runoff. While conservation programs like Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP) are increasing in popularity, the funding of these programs is limited reducing their effectiveness in addressing runoff issues because of the limited acres involved. It appears the funding of these programs will decline as the political atmosphere tends toward a self sustaining agricultural economy. Preservation of wetlands could be impacted by these program changes.

Wetlands of the Upper Mississippi River Basin

Wetlands in the upland areas of the basin are recognized for biodiversity, for water quality, and to their potential use for flood redirection in the basin. The amount of presettlement wetlands in the basin is estimated at 58 million acres (Kusler, 1993). Presently there are about 23 million acres of wetlands remaining in the basin. In many areas of the pothole region such as the DesMoines and Minnesota River basins, over 90 percent of the hydric soils are drained or used for agricultural purposes. The drainage of these wetlands has altered runoff patterns from these pothole regions and in most cases it can be argued that this practice has increased flooding downstream. Table 1 displays an estimate of current wetlands status in the study area by state.

Table 1

Percentage of wetlands in States circa 1780 and present (after Dahll1990).

State	Percentage of Wetlands 1780	Percentage of Wetlands Present
Illinois	22.8	3.5
Iowa	11.1	1.2
Minnesota	28.0	16.2
Missouri	10.9	1.4
North Dakota	10.9	5.5
South Dakota	5.5	3.6
Wisconsin	27.3	14.8

Sources of Information

The volume adjustments used in the FPMA for the sensitivity analysis of runoff reduction measures were adopted based on results from case studies conducted for the "Preliminary Report of the Scientific Assessment and Strategy Team" (SAST) and on the judgement of engineers and scientists with intimate knowledge of the land resources of the Upper Mississippi River Basin. Table 2 summarizes the SAST case study analysis. Knowledge of the land resources was acquired through the 1992 Natural Resource Inventory (NRI) and the cooperation of the Natural Resource Conservation Service (NRCS) Midwest National Technical Center, Lincoln, Nebraska. The NRI defines land use by major use categories and provides this information for each major tributary of the Mississippi and Missouri River basins. The data base provides reasonable landuse statistics for unit areas down to about 500,000 sq. mi., which was adequate resolution for the landuse analysis for the area being assessed for the 1993 flood. This NRI data can be used to estimate the upland land use and soils characteristics and how changes in land use may effect runoff.

Table 2

SAST Watershed Analysis Results

Percent (%) Flood Peak and Volume Reduction by Watershed and Treatment

(Revised)

	Boone River		West Fork Cedar River		Whitebreast Creek		Redwood River	
Return Period	**Peak**	**Volume**	**Peak**	**Volume**	**Peak**	**Volume**	**Peak**	**Volume**
Flood Plain Wetlands								
1	5	0			1		6	1
5	3	0			1		5	1
25	2	0			2		3	1
100	2	0			0		3	0
Upland Wetlands or Potholes								
1	9	7					23	2
5	8	4					15	3
25	7	1					11	4
100	5	0					10	2
Conservation Reserve Program (CRP)								
1	3	2	7	6	4			
5	1	1	5	4	4			
25	1	1	4	3	4			
100	1	1	3	3	4			
Maximum Infiltration (FSA) - Includes CRP Reductions								
1	6	4	15	14	21			
5	3	3	11	10	15			
25	2	2	8	8	18			
100	2	2	7	7	20			
Detention Structures								
1					8		26	4
5					15		16	4
25					27		12	5

100					28	11	3
Total of All Applicable Treatments							
1	18	12	15	14	29	27	11
5	14	8	11	18	21	21	12
25	12	4	8	8	37	17	12
100	9	2	7	7	40	16	11

The NRCS uses hydrologic runoff curve numbers (CN's) to indicate surface runoff potential from various soil-cover complexes. Change in land treatment affects curve number. An increase in soil surface cover resulting from FSA-FACTA measures reduce CN's resulting in higher infiltration and lower runoff. This method will facilitate the analysis of flood volume reductions as a result of land treatment and its relative impacts when related to flooding in the lower mainstem floodplains for a range of flood frequencies.

The SAST case studies evaluated the effects of combinations of land use changes on four selected watersheds which represent four distinct landforms in the Upper Mississippi River Basin. These study areas are rather small tributaries (500,000 acres or less) in relation to the drainage areas contributing to the downstream floodplains being assessed. The study areas include four landforms: 1) a steep basin, 2) a low relief pothole basin, 3) a low relief basin with well defined drainage and 4) a relatively high relief basin that has been drained for agriculture. The studies were not conducted using the same hydrologic model, but general trends were identifiable and relative differences could be noted from the studies. These studies indicated that reductions in flood peaks from upland land treatments can be influenced by many factors. The floodplain geomorphology, hydrologic characteristics, antecedent conditions and precipitation distributions are some of the factors. The studies also indicate a trend toward decreasing influence on flood magnitudes as precipitation or flood recurrence interval increases. Where land use changes may reduce flood peaks by between 25-50 percent and flood volumes by 10-20 percent for a flood with a return period of 2-5 years, the same changes may only reduce peaks by 10 percent or less and volumes by 5 percent or less for floods with return periods of 100 years or greater. However, further modeling is needed to determine actual peak reductions in the upper tributaries where timing of runoff the basin shape are more important.

FPMA Assumptions and Limitations

The schedule and funding allocated to the FPMA did not permit a detailed analysis of current land use and how it affected flooding over the entire area impacted in 1993. Models exist which represent small portions of the basin, but not to the extent that they would provide appropriate coverage to perform detailed, comprehensive analysis on this very diverse landscape. However, existing data does provide a some level of understanding of these physical features and processes. Estimates on how land use changes will affect volume relationships could be developed for the mainstem rivers to the level of detail

commensurate with the assessment's objective.

Since the measures were to be weighed against 1993 flood conditions, the volume reductions and measures assumed had to account for the extreme antecedent conditions that existed in these watersheds during the critical months of June through July. Reductions of 5 and 10 percent were adopted as a representative range for adjustments in volume for conditions present during the 1993 flood. They are not intended to represent the influence watershed changes could have under normal antecedent conditions. The 10 percent reduction is considered an upper bound on what may be achievable for the basin under 1993 conditions. In some tributaries where flooding was most severe, reducing volumes by 10 percent would require significant structural measures.

These reductions were used to test the sensitivity of the floodplain water surface profiles to changes in tributary hydrograph volumes based on the 1993 flood hydrographs. The reductions were intended to represent changes in watershed management practices as current agricultural programs and policies are changed to achieve best management practices. The measures would be in addition to the measures currently in place in the respective watersheds. The non-structural measures or land treatments considered would include measures such as increasing wetland storage, changes in depressional hydric soils drainage patterns, maximizing infiltration through use of conservation practices and cropland conversion. Structural measures would include measures such as road retention structures, the traditional SCS small (P.L. 566) watershed structures, and larger flood storage structures such as those operated by the COE where necessary.

Conclusions

Restoration of upland wetlands and aggressive use of other structural and non-structural measures would have produced some localized flood reduction benefits, but would have had little effect on mainstem flooding caused by the 1993 event. Case studies conducted by the COE using the 1993 tributary hydrographs and upland land treatments indicate that the effects of volume reductions diminish as the size of the drainage area increases. The case studies indicated that 10 percent uniform volume reductions of all upland hydrographs resulted in peak flow reductions of 5 percent or less in the lower floodplains . The studies demonstrate that flood peaks in the lower floodplains of the Mississippi and Missouri River mainstems are more sensitive to timing than to individual tributary hydrograph volumes or peaks.

Hydraulic modeling of the upland watershed volume reductions predicted average stage decreases of about 0.7 foot and 1.6 feet, respectively, on the upper and middle Mississippi River and about 0.4 foot and 0.9 foot, respectively, on the lower Missouri River. Non-structural flood control measures alone would not have achieved this level of runoff reduction for the 1993 event because of the extremely wet antecedent conditions. Studies have demonstrated that wetlands may reduce local flooding in the uplands by up to 25 percent where contributing areas are small. However, restoration of these wetlands combined with other non-structural measures had only minor effects on flooding in the lower floodplain reaches for the 1993 flood.

Changes in upland land use and the potential to reduce flooding in upland floodprone areas varies. The potential for flood damage reduction through changes in upland land use policies and programs is universally debated. The political, social and economic issues surrounding this debate are very complex. The FPMA has addressed some of these issues within the context of the 1993 flood. However, further study of these complex upland land use issues is required such that more reliable information is available for policy makers to reshape floodplain policies and programs for the future.

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An Assessment of Aquatic Resources in the Southern Appalachians

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The Southern Appalachian Assessment (SAA) presents current conditions, trends, and impacts on the environment to assist those involved with resource planning for ecosystem management. Four SAA Technical Reports address terrestrial resources, aquatic resources, air quality, and social/cultural/economic aspects in the Southern Appalachian Mountains. The SAA is a cooperative effort of the USDA Forest Service, U.S. Environmental Protection Agency (EPA), Tennessee Valley Authority (TVA), U.S. Fish and Wildlife Service (USFWS), U.S. National Biological Survey, and the National Park Service.

The SAA Aquatic Resource Technical Report compiles existing regionwide information on aquatic resource status and trends, riparian condition, impacts of various land management or human activities, water laws, and aquatic resource improvement programs and water uses. The report discusses the distribution of aquatic species and has identified impacts on aquatic resources and water quality. Some problems include numerous degraded streams (greater than 20 percent of stream miles impacted in 13 basins), eutrophication of lakes (approximately 38 percent), habitat stress such as loss of up to 75 percent of riparian forest in some watersheds, loss of aquatic species, and the impacts of increasing human population and development. The report further identifies cooperative opportunities for citizens, businesses, and government agencies and recognizes future data needs for aquatic resources.

Biological diversity of aquatic species is high, with a rich fauna of fish, molluscs, crayfish, and aquatic insects. Although some human activities that impair aquatic habitat have decreased, population growth and concomitant land development have the potential to increase pressure on aquatic resources. The heritage program files indicate there are 190 aquatic species that are endangered, threatened, or of special concern within the SAA area. These include 26 endangered mussels and 7 endangered fish. Mussel populations may experience additional declines over the next 30 years in the Tennessee River Basin. Impoundments of rivers and degradation of water quality have been implicated in the loss of these mussel species. Approximately 39 percent of the SAA area is in the range for wild trout, consisting of 33,088 miles of potential wild trout streams. The three trout species within the SAA area are vulnerable to stream acidification, which is increasing, particularly in higher-elevation streams.

While the percentage of degraded streams in the study area cannot be estimated accurately with available information, evidence documented in this aquatic resources report is instructive.

First, states' assessments of designated use support for aquatic life, drinking water, recreation, and other water uses show that approximately three-quarters of all drainages in the SAA area have at least 6 percent of their streams not fully supporting uses (see Chapter 2.2). Many drainages have greater than 20 percent of stream miles that do not fully support uses. Because most states' monitoring programs cover only a small fraction of waters and their monitoring network locations are not chosen to represent all streams in the SAA area, we can consider the range of 6-20 percent degraded streams to be a lower bound estimate, primarily for larger streams. Second, studies of selected portions of the SAA area, using

fish community biological samples of smaller drainages in several basins (see Chapter 2.7) suggest that over 70 percent of locations sampled show moderate or severe fish community degradation. Third, a statistical sample of stream habitat condition overlapping the portions of the study area in Virginia and West Virginia suggests that about 50 percent of stream miles in the area studied show habitat impairment compared to relatively unimpacted reference conditions (see Chapter 3.1). Because these estimates are inadequate to represent the entire SAA area, a comprehensive statistical sample of streams in the SAA study area is necessary to determine the extent of degraded streams with known confidence. Repeating such a sample would help document improvement (or decline) of water quality over time. Impacts associated with both urban and rural development in the SAA area are likely to continue until watershed management and planning are implemented across the region as a whole.

Water quality laws and regulations have been effective in controlling most point sources of pollution. In addition, widespread application of effective Best Management Practices (BMPs) to nonpoint sources of pollution can potentially be effective in protecting and maintaining water quality.

Finally, this Aquatic Resources Assessment outlines information and data gaps which should be filled to allow evaluation of changes in aquatic conditions over time and more reliable evaluation of the effectiveness of water quality protection efforts. These data gaps point to ready opportunities for federal and state agencies with water quality interests to jointly refine, calibrate, and use sensitive biological, physical habitat, and chemical indicators of aquatic ecosystem condition and to collaboratively monitor the resource (Intergovernmental Task Force on Monitoring Water Quality 1994) to ensure that aquatic resources are improving over time.

Questions and Key Findings

The Aquatic Resource Technical Report addresses five questions raised during public outreach of the proposed SAA. Government agency scientists from various levels, forest planners, and concerned citizens identified the five questions as necessary to the understanding of the unique Southern Appalachian ecosystem being studied. The following example key findings highlight results of the assessment addressing each question.

Question 1/Chapter 2.0 *What is known about the current status and apparent trends in water quality, aquatic habitat, and aquatic species within the Southern Appalachian study area?*

- Water is a significant part of the SAA area landscape. The mean density of stream and river channels is 12 feet per acre and would be greater if all small mountain streams could be measured.
- The trophic status of lakes in the SAA area varies widely. Overall, for lakes greater than 500 acres assessed by the states, 38.0 percent of lake acres were assessed as eutrophic, 46.0 percent mesotrophic, and 16.0 percent oligtrophic.
- There are 15 large watersheds where greater than 20 percent of stream miles have impaired water quality.

- Within the SAA area, 54 percent of stream miles have high sensitivity to acid deposition, 18 percent have medium sensitivity, and 27 percent have low sensitivity.
- Projections for the future suggest that additional streams could become more acidic in the decades to come. The northern part of the Assessment area is more vulnerable because of climate and proximity to sources of acid deposition. Headwater mountain streams in rugged terrain are typically most sensitive to acid deposition.
- The heritage program lists include 190 aquatic and semiaquatic TE&SC species in the SAA area; of these, 62 are fish and 57 are molluscs.
- Of the 34 endangered species on the state heritage program lists, 26 are molluscs and 7 are fish.
- Of the 58,477 square miles in the SAA area, 22,785 square miles are in the range of wild trout. Trout also live in some areas of the Southeast that are outside the SAA area.
- Approximately 59 percent of wild trout streams are in areas that are highly vulnerable to acidification and 27 percent are in areas that are moderately vulnerable to acidification. Most of the highly vulnerable areas are in the northern parts of the SAA area, where brook trout is more common than rainbow and brown trout.
- A total of 260 other aquatic Species at risk exist in the SAA area: 97 fish, 25 mussels, 1 snail, 2 crayfish, 111 insects, 17 salamanders, and 7 turtles.
- Fish that are categorized as TE&SC species or as other aquatic species at risk (table 2.6.1) comprise about 45 percent of the total number of fish species in the SAA area.
- Mussels that are categorized as TE&SC or as other aquatic species at risk comprise about 50 percent of the total mussels found in the SAA area.
- Detrimental impacts on fish community integrity are evident from fish community samples conducted by state and federal agencies covering selected subsets of the SAA area. Of 300 subjectively selected sites in both the Ridge and Valley and Blue Ridge ecological regions, about 69 percent of streams sampled show moderate to severe degradation.
- A statistical sample or a much larger and more widely distributed selection of sites would be needed to completely describe fish community condition in the study area.
- About 60 percent of the reference streams on the George Washington National Forest that have low EPT (see glossary) scores were acidified (acid neutralizing capacity [ANC] < 100).

Question 2/Chapter 3.0 *What Management Factors are Important in Maintaining Aquatic Habitat andWater Quality? What is the Extent of Riparian Area and Composition?*

- A number of streams in the SAA area are likely to evidence habitat degradation based on studies of subsets of the SAA area. Qualitative visual habitat assessments of 235 sites in the Holston and Hiwassee drainages show 15 percent of the sites sampled were severely impaired, 62 percent slightly to moderately impaired, and 23 percent not impaired. Qualitative visual habitat assessments of 178 statistically selected sites in the Mid-Atlantic Highlands Assessment (MAHA) study area (this includes the SAA study area in Virginia and West Virginia and also some areas outside the SAA) estimates that 50 percent of stream miles have impaired physical habitat. Approximately 37 percent of stream miles in the Blue Ridge ecological regions of the MAHA area and 60 percent of stream miles in the Ridge and Valley ecological region of the MAHA are impaired, due to habitat factors.

- Land cover classes thought to strongly influence water resource integrity are distributed in the study area as follows: forest--70.7 percent, pasture/herbaceous--21.8 percent, cropland--3.5 percent, developed/barren--3.8 percent, and wetlands--.02 percent.
- Intensive human influence on landscapes in the study area ranges from 0.0 percent to 74.6 percent. Intensive human uses include the developed/barren, cropland and pasture/herbaceous classes. (Note: Developed/barren includes rock outcrops, and herbaceous includes mountain balds which may receive little or no human use.)
- Aggregated land cover classes for the riparian zone of the entire SAA area are distributed as follows: forest--69.9 percent, pasture/herbaceous--22 percent, cropland--3.1 percent, developed/barren--4.3 percent, and wetlands--0.7 percent.
- Federal holdings, including National Forest System and National Park land, have 90 percent forest cover in the riparian zone. Private lands in the SAA area have 60 percent forest cover in the riparian zone.
- Forest cover in the riparian zones of the study area ranges from less than 25 percent to 100 percent.

Question 3/Chapter 4.0 *What Laws and Policies for the Protection of Water Quality, Streams, Wetlands and riparian Areas are in Place and How Do They Affect Aquatic Resources, Other Resources and Human Uses Within the SAA?*

- A number of federally funded programs do exist to protect, restore, or improve the aquatic resources within the SAA. The programs are sponsored by a number of agencies including the USDA Forest Service, NRCS, NPS, FSA, EPA, TVA and the U.S. Army Corps of Engineers. To cite a few examples, the programs provide for cost-share technical assistance to private landowners for erosion control, the purchase of easements on private wetlands, restoration, and assistance to private landowners for riparian management.

Question 4/Chapter 5.0 *What are the Current and Potential Effects on Aquatic Resources From Various Activities? What Species and Habitat Types are at Most Risk?*

- Two-thirds of the reported water quality impacts are due to nonpoint sources, such as agricultural runoff, stormwater discharges, and landfill and mining leachate.
- In the majority of counties in the SAA area, less than 30 percent of the land base is devoted to agriculture. Those counties with more land in agriculture do not necessarily have greater estimated erosion potential, but often do have grater estimated nitrogen loading from fertilizer and animal manure.
- Population in the SAA increased 19 percent from 1970 to 1980. Growth increased 7 percent more in the next 10 years. Development of housing, service facilities, and roads to serve the growing population generally increases impacts on water quality.
- Mining, urban/suburban development, and dams have made the largest alteration in hydrology in the SAA region.
- Forest comprises the primary land cover of the region. Unlike agriculture, forestry activities that disturb soil are dispersed in both space and time. Thus, forestry has a lower potential impact on

aquatic resources.

- Urban areas and paper mills are a large source of biological oxygen demand (BOD). Waters with estimated high BOD loading are often in watersheds that have more miles of stream that do not support designated uses.
- A total of 17 fish consumption advisories have been issued in the SAA area, each state having at least one of these advisories. Eleven of the warnings are for PCB contamination, one is due to PCB/chlordane contamination, three are due to mercury contamination, and two are due to dioxin contamination. Of the 17 advisories, 10 are located on 4 rivers and a lake that cross state lines.

Question 5/Chapter 6.0 *What is the Status and Apparent Trends in Water Usage and Supplies Within the SAA, Including Water Rights and Uses on National Forest System Land?*

- In 1990, approximately two-thirds of the water use within the study area was industrial, with the remainder divided between commercial, domestic, and agricultural.
- Overall, water usage in the domestic, industrial, and agricultural categories decreased 19.6 percent between 1985 and 1990, primarily due to a 26.6-percent decline in industrial use. Agricultural and domestic use also decreased, whereas commercial use increased.
- Water usage on National Forest land is minuscule in comparison to county usage.

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Water Quality and Farming Practices in an Agricultural Watershed

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

Modern agricultural practices rely heavily on the use of agricultural chemicals for weed control and commercial fertilizers to supply plant nutrients. Nonpoint source pollution has been linked to agricultural practices because the inputs used in farming have been detected in both surface and ground-water surveys across the United States. Herbicide use is the most intensive in the Midwest and there is concern over the fate of these chemicals (Gianessi and Puffer, 1990). Goolsby and Battaglin (1993) analyzed data from surface water samples from the Midwest and found that concentrations and mass transport of herbicides follow an annual cycle. In their reconnaissance study, several of the drainage basins in the Mississippi River watershed were sampled beginning in 1989. They found that less than 3 percent of the herbicide mass applied to cropland was transported into streams; however, this mass was sufficient to cause atrazine concentrations to exceed the 3 ‘g/L drinking water standard in the Mississippi River for short periods of

time. The peak herbicide concentrations were found in storm runoff in May, June, and July with some detections throughout the year. Concentrations were related to the amount applied. Nitrate-nitrogen concentrations throughout the year exhibited a different pattern than herbicides with the highest concentrations in the winter and spring and the lowest during the summer. Kolpin et al. (1993) found detectable herbicides or atrazine metabolites in 28.4 percent of the 303 midwestern wells sampled in 1991. None of the wells sampled had herbicide concentrations that exceeded standards for drinking water. Nitrate has been found in shallow ground water samples in the Midwest. Burkart and Kolpin (1993) found nitrate-nitrogen above the 10 ppm MCL in 6 percent of their samples. Detections above 10 ppm vary among the states of the Midwest.

Management practices within fields influence the occurrence and movement of herbicides and nitrate-nitrogen in soil and water resources, yet the processes controlling offsite movement are not clearly understood. A regional scale effort began in 1990 to evaluate the effect of farming practices on water quality. As detailed by Onstad et al. (1991) the Management Systems Evaluation Area (MSEA) program has two main goals: 1) to evaluate the distribution of agricultural chemicals in water resources and identify the processes and factors that affect distribution, and 2) to develop alternative and innovative agricultural management systems that enhance and protect water quality. Quantitative approaches based on environmental quality standards have not been used in the development of improved management practices. The MSEA program is a regional effort and covers 10 sites in the Midwest with research centers in Iowa, Minnesota, Missouri, Nebraska, and Ohio. Walnut Creek watershed in central Iowa on the Des Moines Lobe landform region was chosen as a site for evaluation of the integrated effect of farming practices on surface, tile drainage, and shallow ground-water quality.

Experimental Setting

Details on Walnut Creek watershed have been presented in Sauer and Hatfield (1994). Walnut Creek is an intensively cultivated watershed with almost 90 percent of the cultivated area in a corn-soybean rotation. The remainder of the land is divided among oats, alfalfa, grass, and trees. Topography of the watershed is rolling with no defined surface runoff patterns in the western portion of the watershed due to the presence of the prairie pothole landform. Soils within the watershed are poor to moderately drained with the soils in the potholes a poorly drained Okoboji soil. These poorly drained areas are connected with a series of tile drain lines that course through the landscape and empty into streams along the field edge. The pattern of the tile drains in the watershed resembles an underground stream network. The soils within the watershed are predominantly from the Clarion-Nicollet-Webster soil association and are highly productive soils with a large water holding capacity. In the lower portion of the watershed with a more sloping landscape, surface runoff is more dominant. Walnut Creek discharges into the Skunk River, and the alluvium area along the river serves as a water resource for communities located along the river. Water for drinking is removed through wells placed in the alluvium material.

Transport of agricultural chemicals is the major focus of the research conducted within Walnut Creek. Atrazine, alachlor, metribuzin, metolachlor, and nitrate-nitrogen are monitored in shallow and deep ground water, surface water runoff, tile drainage water, stream discharge, and precipitation. The interactions between farming practices and water quality are evaluated in different parts of the hydrologic system.

Monitoring has been conducted since 1990 within selected stream sites and since 1991 on components of the hydrologic system. Stream monitoring is conducted with a combination of a weir and water depth gauge, PS-2 (Parascientific Inc.)1, to measure discharge and an ISCO water sampler model 37001 to collect water samples. These units are connected through a Campbell Scientific Instrumentation CR-101 data acquisition system that was programmed to collect a sample at the onset of an event and to sample during an event both on the rise and fall of the stream level. In the absence of any change in discharge, the unit collects a weekly sample. Nested piezometers are installed around the edge of selected fields in a series of depths to sample different portions of the shallow ground water. Water use rates are measured in selected fields with a Bowen Ratio system that provides an estimate of crop water use.

Tillage practices, herbicide rates and formulations, and fertilizer use records are collected for every field within the watershed through farmer surveys. There are over 70 operators within the watershed and these are surveyed each year. Data collected for each field are placed in a ARC/INFO data base in order to provide a Geographical Information System (GIS) coverage of the watershed. Field records are combined with the water and soil observations to relate farming practices to environmental quality. Intensive studies are conducted in specific fields to evaluate the movement of herbicides and nitrate-nitrogen in the soil, the movement of water within the landscape around potholes, and the spatial variation of soil properties and responses to different tillage practices within a field. Observations are collected with a Global Positioning System (GPS) in order to provide georeferenced coordinates to relate the sampling site to specific soil map units and field locations.

Results

Surface and Tile Drainage Water Quality

Tile drainage within Walnut creek is the primary conduit for water movement. Approximately 45 percent of the precipitation is returned to the atmosphere through evaporation either from soil or plants, 45 percent is drained from the soil profile through the tile drains, and the remaining 10 percent is available for movement to the shallow ground water. These amounts vary among years depending upon the precipitation pattern. Tile drainage is the primary pathway of herbicide and nitrate-nitrogen movement from fields to the stream. There are different patterns of nitrate-nitrogen and atrazine movement in the tile drains. As the flow increased, the nitrate-nitrogen concentrations decreased and the atrazine increased (Figure 1). There is a responsiveness of individual tile drains to precipitation events.

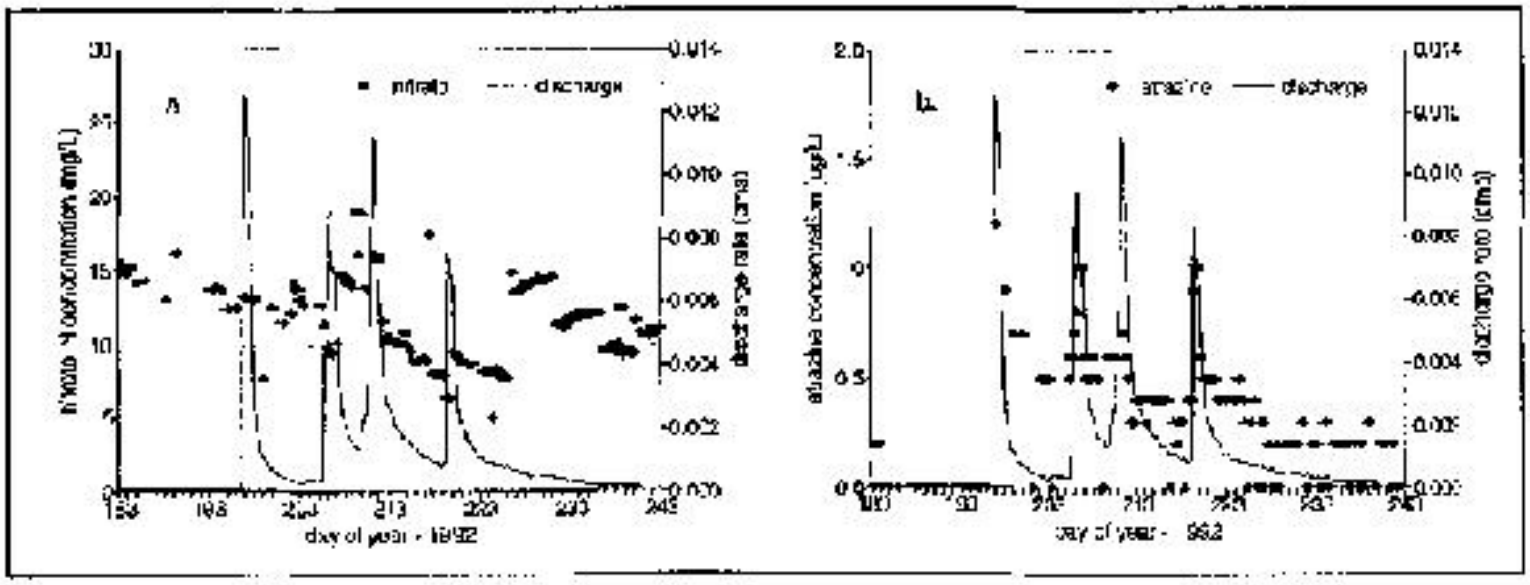

Figure 1. Hydrograph of tile flow and nitrate-N concentrations (a) and atrazine concentrations (b) in a single field drain tile from a 10 ha field in Walnut Creek watershed during July and August, 1992.

Surface runoff is a relatively small portion of the water balance and is less than 1 percent of the stream discharge in a typical year. Surface runoff events occur primarily in the early spring or late winter when there is snowmelt on frozen soil. Within Walnut Creek there is some surface runoff from the edge of fields next to the stream. Summer events are possible. In 1991, runoff events caused atrazine concentrations in the stream to rise to 25 æg/L and metolachlor to 80 æg/L; however, these were short-lived events that were less than 1 hour duration. In 1992 with similar runoff, however, events were later in the season and there were no detectable increases in the atrazine or metolachlor concentrations in the stream.

Relatively little atrazine and metolachlor, and negligible amounts of alachlor and metribuzin are lost from the watershed in stream discharge. Annual chemical loads and application amounts to the watershed are shown in Table 1. Losses of atrazine are less than 2 percent; however, 1993 had losses up to 7 percent. Atrazine and metolachlor show the largest loads in discharge. Amounts lost during 1994 were the smallest of any year sampled to date and if we assume similar application amounts to the previous years, then these losses would be less than 0.2 percent for atrazine and less than 0.1 percent for metolachlor. Nitrate-N loads from the watershed range from 40 to 150 percent of the total fertilizer applied. Concentrations of nitrate-nitrogen in the tile drains range from 15 to 20 mg/L in the spring to less than 10 mg/L in late summer and early fall.

Table 1. Annual applications and loads (kg) lost from Walnut Creek watershed for nitrate-N, atrazine, alachlor, metribuzin, and metolachlor. (Application amounts are not available for 1994.)

	Nitrate-N	Altrazine	Alachlor	Metribuzin	Metolachlor

Year	Appl.	Load	Appl.	Load	Appl.	Load	Appl.	Load	Appl.	Load
1991	237300	98200	740	17.89	665	3.65	65	0.15	2549	31.93
1992	284860	143200	850	5.68	363	0.04	16	0.01	2369	8.47
1993	227040	337100	526	38.99	391	0.88	105	0.13	1648	34.52
1994		19800		1.25		0.01		0.01		1.10

Shallow Ground-Water Quality

A series of piezometers have been placed around fields to collect information on the depth of the water table and to collect water quality samples. Shallow ground-water quality shows little nitrate-N moving below 3 m, and concentrations observed in the wells deeper than 4.6 m average 2.1 mg/L. Samples exceeding the 10 mg/L MCL for nitrate-N in drinking water decrease with depth from 75 percent at 0 - 0.9 m to only 4 percent at greater than 4.6 m, and the percentage of samples exceeding the 1 mg/L limit decreased from 100 percent at 0 - 0.9 m to 67 percent at greater than 4.6 m. Little herbicide is found at any depth. Mean concentrations are below 0.1 æg/L. Most samples did not contain herbicides above the quantitation limit of 0.2 æg/L. One observation of atrazine above 3 æg/L was made in a well 1.5 - 3 m deep. Unlike nitrate, no trend was found for herbicides except atrazine in either mean concentrations or frequency of detection. Atrazine was detected more frequently at depths of 0.9 to 1.5 m and at 1.5 to 3 m increments. Only two, one for atrazine and one for metolachlor, of more than 1,700 water samples exceeded the level of 3 æg/L. Overall, despite the frequent use of nitrogen fertilizers and herbicides (atrazine and metolachlor in particular), fertilizers and chemicals are not found in concentrations above the quantitation limit in the shallow groundwater system.

Conclusions

Walnut Creek has proven to be a valuable study site to integrate farming practices with observations of water quality in various parts of the hydrologic system. The tile drainage network across the landscape provides a sample of the herbicide and nitrate-nitrogen moving through the root zone. Concentrations of herbicides are typically less than 1 æg/L and are often near the 0.2 æg/L quantitation limit. Nitrate-nitrogen concentrations range from 15 to 20 mg/L in the tile drainage water. Tile drains are responsive to precipitation events and during events, herbicide concentrations increase and nitrate-nitrogen concentrations decrease. Surface runoff from fields is not a major source of herbicide movement to the stream. Less than 1 percent of the herbicides are lost from Walnut Creek in stream discharge; however, nitrate-nitrogen losses may average 40 percent of the applied nitrogen fertilizer. There were no areas of the watershed that provided a larger source of herbicide or nitrate-nitrogen than another. To positively impact water quality will require that management practices be implemented across the watershed. This will require a widespread educational effort among all of the land owners and farmers within Walnut Creek. Management changes that would impact nitrate-nitrogen losses would potentially have a positive effect on nitrogen use efficiency and profitability of crop production.

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Watershed Scale Water Quality Impacts of Alternative Farming Systems

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Introduction

Concerns about the impacts of farming on water quality prompted the establishment of the President's Initiative on Enhancing Water Quality in 1989. Five study sites were selected by the United States Department of Agriculture (USDA) to address the water quality issues. These five study sites are known as Management Systems Evaluation Areas (MSEA). A major objective of the MSEA project is to evaluate the impact of alternative farming strategies on surface and ground water quality and to promote best management practices that enhance overall water quality.

Goodwater Creek watershed is the site of Missouri MSEA, located in Audrain and Boone counties in north central Missouri (Figure 1). The watershed covers 77.43 square kilometers and is predominated by claypan soils. Agricultural acreage makes up more than 78 percent of Goodwater Creek Watershed. The dominant crops include corn, soybeans, sorghum and wheat. Mean annual precipitation is 94 cm.

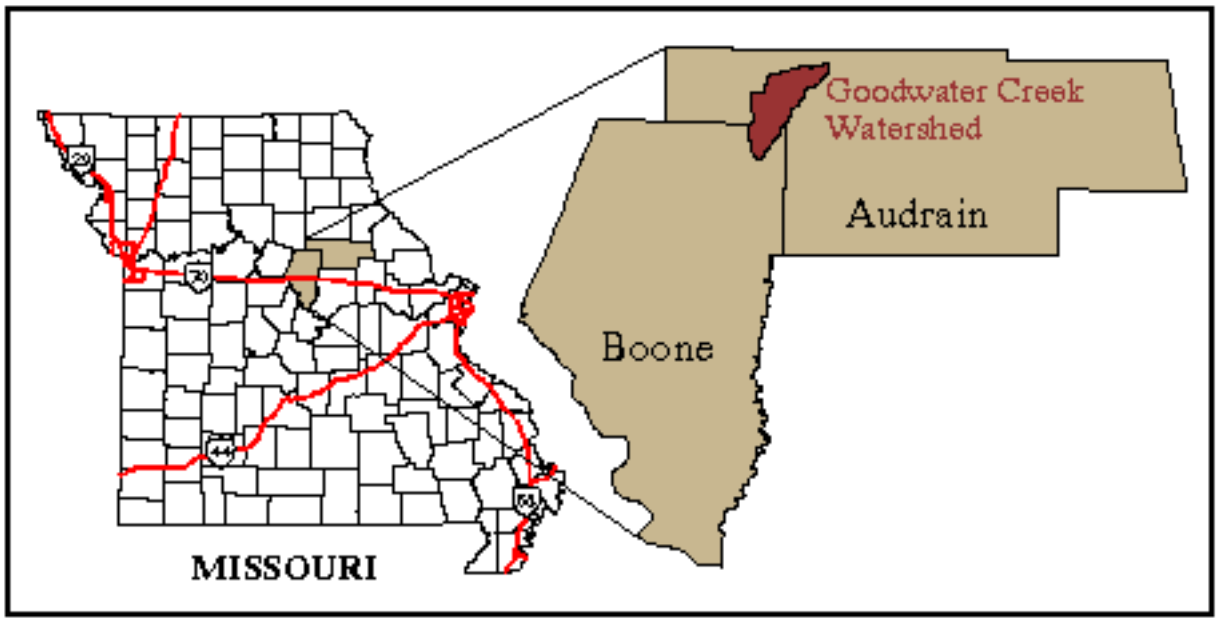

Figure 1. Study area.

Atrazine concentration in surface water is the major non-point pollutant in the watershed. Goodwater Creek is not a drinking water source, however it feeds indirectly into Mark Twain Reservoir which is a drinking water source for communities in northeastern Missouri. Treated water samples from Mark Twain Reservoir have shown that the annual average atrazine concentrations exceed 3 ppb, the maximum contaminant level (MCL) set by the Environmental Protection Agency (EPA) for drinking water (MDNR, 1994). Surface water samples collected from Goodwater Creek show atrazine concentrations ranging from less than 0.2 ppb to over 300 ppb, well over the 3 ppb MCL (MSEA, 1994).

The objective of this project is to develop methods and data for evaluating environmental consequences of alternative land management practices at the watershed scale. In particular, the Soil and Water Assessment Tool (SWAT) model is coupled with a geographic information system (GIS) to evaluate the water quality effects of current (baseline) and alternative farming systems in Goodwater Creek watershed with respect to sediment, nitrates, and pesticide concentrations.

The SWAT Model

The Soil and Water Assessment Tool (SWAT) is a simulation model developed by the USDA Agricultural Research Services (ARS) to predict long-term nonpoint source pollution impacts on water quality such as sediment, nutrient and pesticide loads at watershed and sub-watershed levels (Arnold et al., 1994). SWAT is a process-based continuous daily time-step model, and is capable of simulating long periods of output for computing the effects of land management changes.

Model inputs include management inputs such as crop rotations, tillage operations, planting and harvest dates, irrigation, fertilizer use, and pesticide application rates, as well as the physical characteristics of the watershed and its subbasins such as precipitation, temperature, soil type, land slope and slope length, hydraulic conductivity of soils and stream channel alluvium, channel length, width and slope, Manning's

n values and USLE K factors. SWAT simulates water balance (i.e. surface runoff, return flow, percolation, evapotranspiration, and transmission losses), crop growth, nutrient cycling, and pesticide movement. Model outputs include watershed and subbasin values for each component.

Methods

The goal in applying SWAT to Goodwater Creek watershed was to approximate the actual land use patterns in the watershed as closely as possible. The modeling procedure used in this study attempts to ensure that the nutrient and pesticide uses are well represented in each of the 20-year simulations.

The watershed was divided into 58 natural subbasins based on a digital elevation model of the watershed. Each subbasin was further subdivided into land-use based virtual subbasins. Thus, each virtual subbasin contains a specific land use and soil type. As a result, a total of 259 virtual subbasins constitute the Goodwater Creek watershed. Simulated virtual subbasin outputs were averaged to obtain subbasin level values for the water quality components.

The same land use activity was assumed for each virtual subbasin across farming systems. Crop management input files for each virtual subbasin represent current (baseline) or alternative farming systems for the given land use. Each file includes management data such as planting and harvest dates, tillage operations, and pesticide and nutrient application. Respective crop management input files were generated for crops including corn, soybeans, sorghum and wheat for each baseline and alternative farming system. Management practices for other land uses including forest, hay, pasture, and urban are treated as constant from one farming system to another.

The majority of the remaining input parameters was determined using a geographic information system (GIS). Others were derived from measured field data. Daily rainfall data from Goodwater Creek watershed for 1973-1993 was obtained from the USDA-ARS for use in the model.

Atrazine is the pesticide of focus in this study. All of the major corn and sorghum herbicides contain some amount of atrazine, while soybean and wheat herbicides contain none. The baseline crop management inputs were derived based on typical management and the most prevalent pesticides for this region (Becker et al., 1993). Several different herbicide uses were considered typical for corn, sorghum and soybeans, therefore three baseline management alternatives were derived for SWAT simulation. The three baseline alternatives utilize decreasing amounts of atrazine (Table 1). Results for the alternative farming systems were compared to the average of the baselines (B).

Table 1. Management practices of alternative farming systems.

		Atrazine input (kg/ha)		**Nitrogen(kg/ha)**	
Farming system	**Tillage**	**corn**	**Sorghum**	**Corn**	**Sorghum**

Baseline 1 (B1)	Minimum	1.66	1.57	147	109
Baseline 2 (B2)	Minimum	1.55	1.32	147	109
Baseline 3 (B3)	Minimum	1.22	1.16	147	109
Alternative 1 (A1)	Minimum	2.24	1.16	190	109
Alternative 2 (A2)	Minimum	1.66	1.79	147	100
Alternatvie 3 (A3)	Minimum (banded Application)	1.12	0.91	117	112
Alternative 4 (A4)	No-till	2.24	2.24	166	109
Alternative 5 (A5)	Minimum	2.24	1.68	146	95.2

The alternative farming systems were styled after Missouri MSEA farming systems which represent a range of crop yield goals and management inputs, including nitrogen and pesticide application rates and tillage operations (Table 1). The management alternatives used in this model include high atrazine, minimum tillage (A1 and A5), a medium atrazine, minimum tillage (A2), a low atrazine, minimum tillage (A3), and a no-till option reflecting high atrazine input (A4). In this study minimum tillage is defined as tillage leaving greater than 30% crop residue on the field surface at planting.

Results

Model validation was accomplished by comparing measured crop yields and stream flow against the average of the baseline values calculated by SWAT. Calculated corn and sorghum yields matched measured data closely. Soybean and wheat yields were overpredicted by 28% and 36%, respectively. A statistical comparison of measured versus calculated stream flows indicated a reasonably good fit.

Water quality results analyzed in the study include sediment yield, nitrate concentration in surface and ground water, and peak atrazine concentration in surface runoff.

Sediment Yield

The amount of soil that can be lost each year and still maintain soil productivity is called the soil tolerance (T). T for soils in Goodwater Creek watershed is 11.2 tons/hectare/year as determined by the Natural Resource Conservation Service (NRCS). NRCS data show that all of the crop management alternatives used in this analysis should produce erosion rates well below T. The erosion rates calculated by SWAT do in fact show erosion rates in the expected range.

The largest reduction in sediment yield for the watershed is produced by A4, the no-till farming alternative. At subbasin level, nine of the 58 subbasins exceed T using B although the overall average watershed sediment yield is less than 9 tons/hectare/year. Three subbasins exceed T using A4, the no-till option, and the average sediment yield for the watershed is reduced to less than 7 tons/hectare/year.

Nitrates in Surface Water

SWAT calculations for average surface water NO3 concentrations for the watershed are approximately half of the 10 ppm EPA MCL for each farming system. These values compare well with samples collected from Goodwater Creek, which show that NO3 concentrations in the surface water are generally well below the MCL (Alberts et al., 1993). All of the alternative farming systems show calculated ground water NO3 concentrations lower than the 10 ppm MCL on a watershed average. Ground water for this calculation includes water percolated past the root zone, subsurface flow, and flow lost to the deep aquifer. Subsurface flow is either retained in the shallow aquifer, or is lost to the stream through return flow.

A3, which utilizes side-dressed application of nitrogen fertilizer, gives the largest reduction in calculated ground water NO3 compared to B. Seventeen of the 58 subbasins in B showed ground water NO3 greater than 10 ppm. This compares well with analyses from ground water samples collected from monitor wells around the watershed between 1991 and 1994, which showed that 25% had NO3 concentrations over the MCL (Kitchen et al., 1995). In spite of the overall reduction in ground water NO3 produced by A3, 16 of the 58 subbasins still show a calculated NO3 concentration of over the MCL.

Atrazine in Surface Runoff

Herbicides containing atrazine, which are used for weed control in corn and sorghum, are generally applied in April and May. The highest atrazine concentrations in surface water occur between April and June as a result of runoff from the short, intense Spring storms typical of the region. Peak atrazine in surface runoff were calculated on a basis of weighted average atrazine concentration in the surface runoff for April, May and June, which is the peak runoff period. The three month averages ranged from 58 ppb for A3 to 134 ppb for A4, which is within the same range as the highest measured surface water concentrations in Goodwater Creek in 1992 (Alberts et al., 1993).

Management alternative A3, which utilizes banded herbicide applications at about 1/2 the average application rate is the only alternative that shows a decrease in average peak surface water atrazine concentrations relative to B. A4 shows the greatest increase in average peak atrazine concentration relative to B due to the high application rate necessary for early weed control in a no-till system. A5 also produces a high atrazine concentration due to a high application rate relative to B. Only 10 of the 58 subbasins show average peak atrazine concentrations of less than 3 ppb, all due to lack of corn and/or sorghum in the crop history for those subbasins. The banded atrazine application used in A3 also resulted in average peak surface water atrazine concentrations of less than 3 ppb in 10 subbasins.

Discussion and Conclusion

Water quality effects of management alternatives were evaluated by ranking sediment yield, ground

water nitrates, surface water nitrates, and atrazine concentrations. Overall water quality rankings of the farming systems from best to worst are: (1) A3, (2) A2 and A4, (4) B, (5) A1 and (6) A5.

It is important to note that the level of water quality improvement between B and A3 may not be enough to remove the threat of atrazine contamination in surface water. Peak atrazine concentrations in stream samples collected from the watershed outlet between 1992 and 1994 ranged from around 27 ppb to 112 ppb (MSEA, 1994). The average peak stream concentration for A3 was about half the average peak atrazine concentration produced by B. This is not enough of a reduction to prevent average annual atrazine concentrations in the stream from exceeding the 3 ppb MCL. Additional changes in management practices need to be identified that will further reduce atrazine concentrations in the stream.

The SWAT model provided good results on the watershed scale with respect to stream flow simulation and water quality parameters such as sediment yield, NO3 in surface water and ground water, and atrazine concentrations. It is useful for determining which subbasins within a watershed may be particularly vulnerable to specific water quality contaminants.

Crop yields calculated by SWAT for each management alternative indicate that the yield is not as sensitive to changes in nutrient inputs as would be expected from a crop growth model. Overall the model is not an adequate tool for assessing impacts of agricultural non-point sources of P. Further modifications of the model could make it a more powerful tool in future watershed-scale analyses.

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Watershed Modeling of Pollutant Contributions and Water Quality in the LeSueur Basin of Southern Minnesota

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As part of the Minnesota River Project, the LeSueur Watershed is being modeled with the U.S. EPA Hydrologic Simulation Program - FORTRAN (HSPF) to identify and quantify the relative pollutant contributions from both point and nonpoint sources, and to help evaluate the effects of alternative agricultural BMPs on water quality and pollutant loadings to the main stem of the Minnesota River (see Patwardhan et al, this conference). The Minnesota River is considered the State's most polluted river, with 533 km of main stem and 44,000 km2 of drainage area. Water quality problems are typical of many agriculturally dominated Midwestern states, with low dissolved oxygen, high turbidity, elevated ammonia, and fecal coliform standards violations common during the summer low flow conditions. The HSPF model is being applied to the LeSueur Watershed as an example, or template, for subsequent extension to rest of the entire Minnesota Basin within the State boundaries. This paper briefly describes the model application procedures, watershed representation and preliminary calibration results, along with indications of future modeling directions.

U.S. EPA Hydrologic Simulation Program - FORTRAN (HSPF)

HSPF (Bicknell et al. 1993) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with instream hydraulic, water temperature, sediment transport, nutrient, and sediment-chemical interactions.

The application of HSPF to the LeSueur Watershed follows the standard model application procedures as described in the HSPF Application Guide (Donigian et al, 1984). The major steps in the modeling study include: simulation plan development, database development, watershed segmentation, parameter estimation and input preparation, hydrologic and sediment calibration, NPS loading and water quality calibration, and simulation of alternative watershed scenarios. All HSPF model applications require the development of a simulation plan which documents the overall approach to representing the watershed using HSPF and modeling the hydrology and water quality constituents that are important to satisfying the objectives of the modeling study. It is essentially a planning guide to the modeling effort.

Database Development

Staff of the Minnesota Pollution Control Agency (MPCA) developed the complete database_meteorologic, flow, water quality, pollutant sources_needed for the modeling effort. Flow, BOD5, and TSS datasets were developed by MPCA for all significant sewage treatment plants and stabilization ponds within the watershed. Detailed nutrient and fecal coliform concentrations were not available, and were estimated from tabulations of effluent data for secondary and advanced secondary treatment plants. Nutrient loadings from stabilization ponds were implemented as the product of the estimated monthly discharge and concentration time series for each nutrient form and fecal coliforms, using separate spring and fall discharge concentrations. Atmospheric deposition data were available as dry and wet deposition for the Lamberton, MN site, located about 80 miles west of the LeSueur. Wet deposition is reported in mg/liter on a monthly basis, whereas dry deposition is reported seasonally in grams/square meter. HSPF includes capabilities to handle both types of deposition for all nutrient forms.

Watershed Segmentation

The purpose of segmenting the watershed is to divide the study area into individual land segments that are assumed to produce an homogeneous hydrologic and water quality response. Where the weather patterns vary across a watershed it is necessary to also divide the land segments by meteorology to accurately reflect spatial meteorologic variability and its effect on the hydrology and water quality of the watershed. Four precipitation gages and three temperature gages were used to represent the variability in the primary meteorologic conditions on the watershed, and a Thiesen analysis was performed to calculate the weights associated with each gage/segment combination.

The reach segmentation was designed to represent each of the major tributaries_LeSueur, Cobb/Little Cobb, and Maple_plus one additional for the Lower LeSueur which receives the outflow from all three tributaries prior to discharging into the Blue Earth at Rapidan. The segmentation resulted in 10 stream

segments, ranging in length from 9.7 to 102.6 km, with an average length of 52.5 km and an average drainage area of 285 km2. Lakes were added as additional segments where they controlled significant drainage area. The goal of the lake simulation was to represent the impacts of the large number of individual lakes within the LeSueur Watershed model segments, without the need to model each lake individually. We developed an approach to represent the net impact by including one lake (for each RCHRES segment with significant lake area) that mimics the aggregate effect of the individual ones. This effort required identifying lakeshed areas within each model segment, developing a hydraulic representation for the 'aggregate' lake, and then implementing and evaluating the lake simulation results.

Within each model segment, up to seven different pervious land use (PLS) categories, and one impervious urban/residential category (ILS), were simulated. The categories included Forest, High Till Cropland (Conventional Tillage), Low Till Cropland (Conservation Tillage), Pasture, Urban, Marsh/Wetland, Animal Waste Application area, and Impervious Urban/Residential. Total cropland was divided into the two tillage categories based on data that showed only 3% of total cropland was in a Low Tillage category. The impervious urban (ILS) area was estimated as 30% of the urban/residential category, with the remaining 70% added to the Urban pervious (PLS) area. The Probable Application Area for animal waste applications was derived from an analysis of animal populations, unit animal N and P generation rates, expected losses for storage and application, and an assumption that only 25% of the recommended (or allowable) application area actually received applications.

Model Calibration

Hydrology calibration was performed using the expert system, HSPEXP (Lumb et al., 1994) and following the general guidelines described in the HSPF Application Guide (Donigian et al., 1984). Calibration focusses on developing a reasonable overall water balance among the precipitation, runoff, soil storage, and evapotranspiration components, while comparing observed and simulated flow and snow depths. The calibration achieved reasonable success, with the HSPEXP criteria being mostly satisfied, indicating a good to very good calibration. Volumes are simulated well, the daily flow timeseries generally shows good agreement, and the frequency curves match well. The 'aggregate' lake water balances, depths, and outflows were reviewed and analyzed, and appeared to be reasonable, but further confirmation of the results is needed.

Sediment loading rates were calibrated based on calculated erosion targets and reduced for the expected delivery ratios in the range of 20% to 30%. We first calibrated the loading rates to be in the range of the 20% to 30% delivered load, and then further reduced the rates, especially for the cropland categories since this is usually the major source, in order to get instream concentrations in the proper range. The sediment simulation needs further investigation, as the available data were limited and simulated instream concentration peaks are up to five times higher than the limited observed data, even though the loading rates are much lower than expected.

Results for the Total N and Total P simulations for the LeSueur River at Rapidan are available (Patwardhan et al, 1996). In general, the water quality calibration results are quite promising. Both the

water temperature and DO simulations are quite good, and track the limited observed data well. The BOD simulations are reasonable as the peaks are in the general range of the limited observed data, and appear to be associated with runoff events. BOD is used as an indicator for Organic N and Organic P loads.

The Total N simulation, comprised of NO3-N, NH3-N, and Organic N, is very good. The majority of the Total N is NO3-N, and both the NO3 and Organic N simulations are quite good, and the NH3-N is fair. Also, the loadings for these constituents are in the expected ranges. The Total P simulations, comprised of PO4-P and Organic P, are clearly not as good as the nitrogen, but the data are more limited and are missing during a number of high flow events. The majority of the Total P peaks are primarily Organic P concentrations when observed values were missing. For PO4, the concentrations are all in the proper range except for the August '89 to March '90 period which was during a drought and extreme low flow period.

Closure

The current water quality simulation in the LeSueur Watershed provides a sound basis for extending the modeling to the other Minnesota River subbasins and establishing a comprehensive basis for evaluating alternative management practices to improve water quality in the Minnesota River.

Further water quality calibration is warranted to investigate the problems noted above, especially with regard to sediment and P simulations. At the same time, water quality simulations are proceeding for the other subbasins, and experience gained from those applications will help to further improve the LeSueur water quality calibration.

In this initial effort, issues related to tile drainage, wetlands, lakes, and animal waste applications have been identified and targeted for more detailed modeling in future efforts. In addition, software capabilities are being developed to facilitate the evaluation of alternative conditions and management practices in terms of their expected impacts on pollutant loadings and resulting water quality.

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The Cross-Media Models of the Chesapeake Bay: Defining the Boundaries of the Problem

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Introduction

The boundaries of a watershed are easy to distinguish. Pollutant loads from sources inside the watershed should be accounted for within a watershed management context, but areas outside the watershed are generally not considered. Analyses of the integrated Chesapeake Bay models of the airshed, watershed, and estuary explore the total nutrient loads to the Chesapeake and assist in developing least cost nutrient load reductions necessary for the restoration of the Chesapeake. Increasingly, we are finding that the area affecting a body of water can stretch beyond the boundaries of the watershed. The scale required for attainment of the least cost solution determines the boundary of this larger area. The Chesapeake Bay airshed is estimated to be 910,000 km2, an area more than five times that of the watershed. Emission sources in the airshed contribute about 75% of the atmospheric nitrate deposited on the Chesapeake watershed.

The Chesapeake Bay, like other east coast estuaries, is eutrophic. Excess nutrient loads have reduced water quality and stocks of living resources far below their historic levels. Of the 170.8 million kilograms of nitrogen delivered to the Chesapeake in an average year, 23% are point source loads, 68% are nonpoint source loads, and 9% are air deposition loads directly to tidal Bay surface.

Atmospheric deposition is unique in its ubiquitous nature. Atmospheric deposition is a direct nutrient load when deposited on tidal waters. Atmospheric deposition is also an indirect source, either through deposition on the watershed and subsequent transport to the Chesapeake, or through deposition to adjacent coastal waters and subsequent transport to the Bay. Twenty seven percent of the watershed nonpoint source load delivered to the Bay arises from atmospheric deposition. Work is underway to determine the atmospheric deposition portion of the coastal water nutrient load transported to the Chesapeake.

The Chesapeake Bay Agreement

To reduce nutrient loads to the Bay, the Chesapeake Bay Agreement was forged among the states of Maryland, Pennsylvania, and Virginia, the District of Columbia, and the EPA, which represents the federal government. The Bay Agreement calls for a 40% reduction of the 1985 controllable nutrient loads by the year 2000. In order to track the nutrient sources, the portions of the load that are controllable, and the load reductions possible, an integrated series of linked eutrophication models were developed.

The Simulation Framework

The Chesapeake Bay Program has developed models of the airshed, watershed, and estuary, and is currently expanding the simulation to include selected living resource elements, and adjacent ocean waters. Direct coupling among these models is sometimes necessary, as in the case of the water quality and living resource models which are run simultaneously at each time step and within each model grid. Less rigorous linkage is allowed among the airshed, watershed, and estuarine models, which can be run independently with the output from one model used as input to another.

The airshed model has a three dimensional grid 20 km on each side. The 86 watershed model segments generally follow hydrologic boundaries of river subbasins and the estuarine model has a three dimensional grid of more than 6,000 cells covering the Chesapeake and adjacent coastal waters.

Model History

Watershed Model

The first version of the watershed model was completed in 1982 and the model has been in continuous use since then. The findings of the initial watershed model were the inventory of point source and nonpoint source loads for each basin, and the importance of nonpoint source loads. Subsequent versions of the model came out in 1987 and 1992. The 1987 version demonstrated the importance of animal waste loads in the Chesapeake Bay nutrient budget, and the 1992 version confirmed the importance of atmospheric deposition loads. The Phase III version of the Watershed Model is calibrated and fully operational on the National Environmental Supercomputer Center (NESC). The latest version of the Watershed Model (Phase IV) is due to be completed in the spring of 1996. The U.S. EPA Chesapeake

Bay Program Office is the lead agency for the Watershed Model.

Estuarine Model

The estuarine model began development in 1987 and was completed in 1992 as a linked model with the watershed model. The estuarine model confirmed the water quality benefits of the 40% nutrient reduction goal. The predecessor of the estuarine model was the steady state model completed in 1987. The steady state model simulated steady state summer water quality only , but helped establish the 40% reduction goal and the importance of combined controls of both phosphorus and nitrogen in the Chesapeake. The latest version of the estuarine model will include simulation of major living resource components and is due for completion in early 1997. The U.S. Corps of Engineers Waterways Experiment Station is the lead agency for the estuarine model.

Airshed Model

Work on the airshed model began in 1983 and was completed in 1989. The airshed model has provided predictions of nitrogen deposition to the Chesapeake Bay and watershed under different stationary and mobile source management conditions. The airshed model is calibrated and fully operational at the NESC. The US. EPA National Exposure Research Laboratory is the lead agency for this model.

Linking the Three Models

The first stage of cross-media model development was in 1992, when the watershed model and the estuarine model were linked, and the watershed became internalized in the calculation of Chesapeake water quality. Linkage of the airshed model and Phase III watershed model was completed in 1995. The next stage, will link of the watershed, estuary, living resource, and airshed models, and is scheduled for completion in early 1997. In the second stage of linked model development, all key inputs will be internalized in the cross-media model.

Model Findings

Several key scenarios were used to develop the basic inventory of loads under specific management conditions. Among these scenarios were the 1985 loads, chosen to represent the base case average year. The Bay Agreement scenario represents the reduced nitrogen loads brought about by the Bay Agreement by the year 2000. The Bay Agreement + CAA scenario represents additional reductions in the loads delivered to the Bay under implementation of the Clean Air Act nitrate emission reductions. The limit of technology scenario represents all cropland in conservation tillage and nutrient management, the Conservation Reserve Program fully implemented, animal waste containment and pasture stabilization systems implemented where needed, improved forestry management practices, a 20% reduction in urban loads, and all point source effluent controlled to a concentration of 3.0 mg/l. The no action scenario represents the growth in population and the projected changes in land use by the year 2000. Levels of control in place in 1985 were applied to the year 2000 point source flows and land use.

The linked models predict that in basins where atmospheric deposition of nitrate is highest, such as the Susquehanna and Potomac basins, reductions in nitrogen delivered to the Bay is greatest. In the case of the Susquehanna, nitrogen load reductions under implementation of the Clean Air Act are greater than the current limits of technology for point source and nonpoint source controls. Greater reductions in the delivered nitrogen loads are predicted under implementation of the Ozone Transport Commission (OTC) plan for reducing nitrate emissions. Although the primary objective of the OTC is to reduce harmful levels of ozone in the mid-Atlantic and New England states, the nitrate emission controls called for under the OTC plan will also reduce nitrate loads delivered to the Bay by a further 9 million kilograms over an above the Bay Agreement reduction.

A portion of all nonpoint source loads are due to atmospheric deposition. Cropland nitrogen inputs from fertilizer, manure, and air deposition result in a relatively small proportion of the nonpoint source load (10%) due to air deposition. Hay land receives relatively less manure and fertilizer inputs, so atmospheric deposition is a greater portion of the input, and consequently the output load (23%). Pasture receives no fertilizer input, but does receive manure inputs from pastured animals. Air deposition accounts for 35% of the nonpoint source load from pasture. Forest inputs of nitrogen are solely from atmospheric sources. Thirty seven percent of the forest nonpoint source load is due to atmospheric deposition. Urban inputs of nitrogen include fertilizers, septic systems, and atmospheric deposition. Essentially no attenuation of atmospherically deposited nitrogen on impervious urban surfaces results in a relatively high portion of the nonpoint source urban load to be due to atmospheric deposition (37%). Finally, direct deposition of atmospheric deposition to nontidal water surfaces are accounted for within the watershed.

Conclusion

Quantification of the total loads to the Chesapeake has changed the view that the watershed is the definitive source of nutrient loads. The watershed boundary is no longer the limit which distinguishes precisely the area of concern in coastal eutrophication problems. Added to our lexicon is the term airshed, which is larger than the watershed, and which contributes cross-media nitrogen loads to eutrophic coastal waters.

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Implementing a Rural Watershed Management Plan-Chewelah Creek

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The Chewelah Creek Watershed Management Plan was developed in 1993-1994 as the second phase of the Colville River Watershed Ranking and Planning Project. The watershed ranking and planning process provides an avenue for developing strong local support for watershed related projects. Watershed residents, the people who will ultimately be asked to implement any recommendations proposed by a watershed management plan, are involved in all phases of such a project. The process also provides an orderly method for determining where and when money should be spent through the selection of a number one priority watershed. The Chewelah Creek watershed was selected from among 19 designated subwatersheds in the 650.000 acre Colville River basin to qualify for the development of a watershed management plan. The Colville River is a tributary of the Columbia River in northeastern Washington.

The plan, developed by a watershed management committee comprised of watershed residents and representatives of organizations owning or administering land in the watershed, provides 66 recommendations for activities that will enhance, maintain or protect the water quality in Chewelah Creek and its tributaries and in Paye Creek and Thomason Creek. The efforts of the public, businesses, and government entities are incorporated in the implementation of the plan. The Stevens County Conservation District received a Centennial Clean Water Fund (tobacco tax) Grant from the Washington Department of Ecology to begin implementing some of these recommendations in July 1995. The District hopes to be able to take advantage of the local interest in water quality and watershed related issues, created while the plan was being developed, during the implementation project.

Background

The Chewelah Creek watershed encompasses approximately 66,500 acres (26,800 hectares) in Stevens County, Washington, approximately 50 miles north of Spokane. The watershed has its headwaters area in forested mountains managed by the U.S. Forest Service, Washington Department of Natural Resources, and private industrial and nonindustrial timberland owners. From this point, the two forks of Chewelah Creek and its tributaries flow through agricultural land and rural residential areas. The forks combine to form the mainstem of Chewelah Creek which flows through Chewelah, a city with a population of approximately 2000.

The rural residential areas of the watershed are becoming more populated as more people are willing to have a longer commute to Spokane or are able to fulfill the desire to relocate to a rural setting. The most desirable parcels are those that have surface water in addition to 10 to 20 acres. Much of the land that previously had been owned by a single person will now have numerous owners as forested and agricultural land is sold for rural residences.

Chewelah Creek is an integral part of the city. The creek flows through the city park which is the site of much activity during the summer. Activities include many special events as well as wading, fishing, picnicking and camping. From the park, the creek flows through the business district and through a residential area on its way to the Colville River.

Two creeks, not tributaries of Chewelah Creek, were mapped as part of the watershed because of their location and the fact that they flow through parts of Chewelah. Paye Creek flows through the western part of the city and enters the Colville River adjacent to the city's sewage lagoons. Thomason Creek originates in the forested region east of Chewelah and flows through the southeast corner of the city. These creeks have the potential to be affected by development, existing residences, the city's sewage system and local businesses.

The Chewelah Creek watershed was selected as the number one watershed in the basin based upon the results of one year of basinwide water quality monitoring and a watershed characterization that provided information on the physical and human environment in each of the designated subwatersheds. The reasons behind this selection included:

- It is the third largest of the nineteen designated watersheds;
- The City of Chewelah lies at the mouth of the watershed and the creek is an important feature of the city;
- The creek receives recreational pressure along much of its length;
- The watershed encompasses forest land, agricultural land, rural residential areas and a municipal area;
- The City of Chewelah and the surrounding area have received a great deal of national publicity as being a wonderful place to live;

- A 200 home development has been started along Paye Creek (a significant development for Stevens County);
- More homes are being built on 10 to 20 acre parcels that used to be open or agricultural land; and
- Sediment deposition is evident throughout the entire watershed.

Watershed Management Plan Development

Once the Chewelah Creek Watershed was selected as the number one watershed by the Colville River Watershed Ranking Committee, a Technical Advisory Committee (TAC) and a Watershed Management Committee (WMC) were developed. The TAC aided in data gathering and analysis efforts and was involved in developing a list of plan recommendations. This committee was comprised of technical staff members from local, state and federal agencies as well as local representatives of industry and special interest groups.

The WMC was comprised of watershed landowners, business representatives and elected officials. The committee was responsible for the development of the plan. The Stevens County Conservation District , as lead agency on the project, provided the committee with the necessary information to complete this task and was responsible for producing and delivering all reports on the project.

One of the first tasks of the WMC was to increase their knowledge of the watershed and the watershed management planning process. The committee became informed about the watershed's characteristics, water quality within the watershed, the role of different federal, state and local agencies, and what is involved in developing a watershed management plan. Tours helped committee members obtain a visual picture of the current condition of the watershed and provided a forum for discussion of the various viewpoints held by the different committee members.

The WMC used the water quality and watershed characterization information to identify potential threats to water quality within the watershed. The TAC and the WMC then worked together to develop methods for addressing the identified threats. The TAC suggested a series of alternatives for each potential threat. The WMC discussed each threat by looking at the individual sources of the threat and the alternatives suggested by the TAC. During these discussions, economic, environmental and social impacts were taken into consideration. The WMC was very clear in stating that their objective was to propose voluntary actions by watershed residents as opposed to demanding that certain action be taken through regulatory means.

The recommendations for action proposed in the Chewelah Creek Watershed Management Plan fell under the following headings:

- Camping and recreation - considered the potential for the introduction of bacteria and nutrients into the water as well as degradation of streamside vegetation and streambanks;
- Chemicals - recommendations covered household, commercial, highway/road/railroad, and agricultural chemical uses;

- Contamination sites - recommendations addressed the potential of illegal dumping to contaminate surface water and included making recycling more attractive to watershed residents;
- Excessive aquatic vegetation - Thomason Creek was found to have a very dense mat of aquatic vegetation that blocked fish passage and reduced the level of dissolved oxygen;
- Forest practices - WMC agreed that the Washington Forest Practices Act provides adequate guidelines for all aspects of forest land management;
- Municipal sewage - recommendations addressed the City of Chewelah's 30 year old sewage system;
- Sediment - recommendations addressed sediment sources such as roads, degraded stream channels, livestock grazing, agricultural cultivation practices, and natural erosion processes;
- Septic tanks - acknowledged that the septic systems that provide on-site sewage disposal to numerous watershed residents have the potential to severely impact water quality and that illegal dumping by local septic tank pumping services can have catastrophic consequences; and
- Storm drains - Recommendations were included that would reduce the energy of runoff reaching the creek as well as ways to pre-treat runoff prior to it reaching the creek.
- The WMC acknowledged that there are numerous rules and regulations currently in effect designed to protect or improve water quality and that in some cases the required action is to simply apply what is already in existence.

Plan Implementation

The Chewelah Creek Watershed Management Plan was submitted to the Washington State Department of Ecology in June 1994. The plan was developed with the idea that implementation would occur gradually over the next decade. The committee realized that new technologies and concerns will arise during the time and therefore certain elements of the plan may change.

In 1995, the Conservation District received funding to implement portions of the plan pertaining to sediment and excessive aquatic vegetation in Thomason Creek. The sediment issue is being addressed in part by the development of conservation plans and the use of sediment settling basins. The excess aquatic vegetation is being addressed by upstream source control and mechanical removal of vegetation form the channel.

With an increase in rural residential development has come an increase in the number of "hobby" farms in the watershed. These farms generally have horses but may have a mixture of livestock including cattle, sheep, and goats. Many of these are located on streams and present potential sources of sediment and nutrients due to improper pasture management or the location of animal holding areas. Many of the owners of these parcels have little or no agricultural experience. Conservation plan development will be offered to 30 agricultural operations within the watershed. Large commercial and small "hobby" farms will have the same opportunity for having a plan developed by the local office of the Natural Resources Conservation Service. Farms closer to surface water, with a greater potential to cause immediate impacts on water quality, will be approached first to determine their willingness to participate in this portion of the watershed plan.

Sediment settling basins are proposed for both forks of Chewelah Creek upstream of the city. These basins will reduce the sediment load, no matter what the source, being transported through the city and deposited in the slower moving Colville River. The basins will also provide habitat for waterfowl and each structure will be designed for fish passage. The City of Chewelah, Stevens County, and the Washington Departments of Transportation and Fish and Wildlife will be cooperating with the Conservation District on the design and construction of these structures since all see their benefit to the watershed. The basins are not considered a cure to the sediment problems within the watershed, but when used in conjunction with best management practices, form an integral part of the solution to sediment loading in Chewelah Creek.

Excessive aquatic vegetation was removed by hand from a quarter mile reach of Thomason Creek near its mouth in the fall of 1995. It was determined at that time that further work should involve more aggressive forms of vegetation removal and restoration of the channel through bioengineering techniques. These activities would be combined with upstream measures to address the problems presented by failing septic systems.

Plan Evaluation

The plan proposed a means of evaluating whether the recommendations are actually working as intended. There may be a need to refine certain plan elements and perhaps even change direction in some areas. The evaluation should consider the results and the expenditure of funds. It is possible that funds may be limited in the future, so the evaluation should have the ability to provide direction concerning changes in how funds will be expended.

A water quality monitoring program initiated in 1993 will be expanded to include additional sites within the watershed. The sampling frequency will be reduced to quarterly sampling periods, but a wide range of parameters will be analyzed to obtain an accurate picture of conditions in the watershed. The program will include biological monitoring in the fall and spring and a one time sediment characterization.

Students at the local high school are being incorporated into the monitoring program to help determine sediment loads prior to and after construction of the sediment settling basins. Students will also be involved in the biological monitoring in both the fall and spring.

Other indicators used in an evaluation of the plan would include:

- The quality and quantity of fish habitat throughout the watershed;
- The effectiveness and maintenance of sediment containment structures;
- The success of education programs in reaching the desired audience;
- Evidence of improved maintenance of on-site septic systems; and
- The implementation of Best Management Practices throughout the watershed.

Members of the WMC were asked to continue to serve as an annual review board for the plan. This committee will review water quality monitoring data and other indicators to determine how well the plan is working. An annual report of the results and progress of the plan will be prepared by the committee and the Stevens County Conservation District, the proposed lead agency, for dissemination to the public and funding agencies. The report will summarize the committee's review and status reports from agencies responsible for implementing plan recommendations as well as providing direction for possible revisions to the plan.

Conclusion

The key to successfully implementing the plan has been the ability to work with watershed residents and landowners. Relationships developed during the planning phase have been continued and strengthened. The fact that watershed management planning is based on physical features and not political boundaries has been stressed. People are being informed that their actions may affect people living downstream. The Conservation District is attempting to increase the awareness of Chewelah Creek watershed residents of the potential effects, both positive and negative, of various activities on water quality.

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Model Alliance for Watershed Protection or How to Make a Cart Without Reinventing the Wheel

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Prelude

In 1990, local governments across the country were told by the federal government to make a wheel (i.e., storm water management program). The federal government specified what the parts of the wheel should be made of (e.g., legal authority, public participation), when and how to make it (i.e., Part I and II application deadlines and requirements), and why it was needed (i.e., diffuse sources of water pollution were major causes of water quality problems). In response, each local government started to make its wheel. But local governments found that making a wheel was not a simple process and that it was going to take much longer and require more materials than they had anticipated. It might even require materials from places and sources that they were not aware of or did not have access to normally.

In the San Francisco Bay Area, as each local government got started on its wheel, it noticed that other local governments were also making wheels. First two, then three, and now seven local governments decided that while each was making its wheel, wouldn't it be more cost-effective to make a cart, rather than reinvent the wheel (Figure 1). Hence, the idea for a regional alliance was born.

What is BASMAA?

The Bay Area Stormwater Management Agencies Association (BASMAA), is a consortium of the following seven San Francisco Bay Area municipal storm water programs:

- Alameda Countywide Clean Water Program.
- Contra Costa Clean Water Program.
- Fairfield-Suisun Urban Runoff Management Program.
- Marin County Stormwater Pollution Prevention Program.
- San Mateo Countywide Stormwater Pollution Prevention Program.
- Santa Clara Valley Nonpoint Source Pollution Control Program.
- Vallejo Sanitation and Flood Control District.

In addition to the members listed above, other agencies, such as the California Department of Transportation (Caltrans) and the City and County of San Francisco (combined sewer system), participate in some BASMAA activities. Together, these agencies represent more than 90 agencies, including 79 cities and 6 counties, and the bulk of the watershed immediately surrounding San Francisco Bay.

Why a BASMAA?

BASMAA was started by local governments in response to the National Pollutant Discharge Elimination System (NPDES) permitting program for storm water in an effort to promote regional consistency and to facilitate efficient use of public resources. The organization grew from the bottom (local) up to focus on regional challenges and opportunities to improving the quality of storm water runoff to the San Francisco Bay and Delta. The association is designed to encourage information sharing and cooperation, and to develop products and programs that would be more cost-effective done regionally than could be accomplished locally. In addition, BASMAA provides a forum for representing and advocating the common interests of member programs at the regional and state level. Over its brief history BASMAA has evolved from an organization that promotes talking to each other, to one that shares information and resources, to one that does things together, and finally to an organization that does things with agencies and organizations outside of BASMAA itself.

How is BASMAA Organized?

BASMAA is structured similarly to any local storm water program with committees covering everything from new development to monitoring to public information/participation. BASMAA's organization chart consists of a Board representing the seven municipal programs and the following four committees that report to the Board:

- Monitoring Committee.
- New Development Committee.
- Public Information/Participation Committee.
- Operational Permits Committee.

The Executive Director is staff to BASMAA. He reports to the Board and acts as liaison between the BASMAA committees and the Board, between the committees themselves, and between BASMAA and other organizations and agencies (Figure 2).

How Does BASMAA Work?

The seven member programs of BASMAA have all agreed to the terms of a memorandum of understanding (MOU) that sets policy on member's roles and responsibilities, and describes the purpose and basic operations (e.g., voting, dues) of the organization. Each year BASMAA collects dues from its members for a "baseline" program. The baseline program provides for staff (Executive Director) and finances baseline projects (i.e., projects endorsed by all member storm water programs). In addition, the BASMAA MOU provides a means for two or more of the member programs, or other organizations, to agree to contribute additional funds to do "tasks of regional benefit." This option allows regional or subregional projects to go forward absent a unanimous endorsement by the seven member programs.

Typically, the BASMAA Board and four committees meet monthly on a regular schedule to share information, discuss issues, and manage projects and programs. BASMAA does some projects and programs in-house using BASMAA staff and volunteer time from staff of the member storm water programs. In other cases, BASMAA hires consultants to carry out new projects and programs.

Along with its member programs, BASMAA has been grappling with how to implement the storm water regulations, which cut across typical departmental boundaries, programs, and lines of communication. To do so, these programs have used essentially a watershed approach_involving as many stakeholders as possible and building consensus. Now BASMAA and some of its more mature NPDES permitted programs are expanding the envelope to deal with agencies, issues, and programs that are one step removed from those that they initially focused on. This model alliance that initially focused on urban storm water is now:

- working with the regional air quality district in linking air quality to water quality.
- working to strengthen the integration of storm water and wastewater.
- working with trade associations to develop practical industrial/commercial water quality

programs.

- working with rural-focused agencies and programs in the upper watersheds.

BASMAA does these things not because it or its member storm water programs want to expand their purview and influence but because the linkages to these other areas of our environment and the agencies/organizations that deal with them make for more cost-effective urban storm water programs, let alone more cost-effective environmental programs in general.

BASMAA also works closely with the regional regulator_the San Francisco Bay Regional Water Quality Control Board and the regional estuary research group_SFEI (San Francisco Estuary Institute). In addition, BASMAA works with other regions in the state and with the next level of government up by participating in the California Storm Water Quality Task Force. At the national level, BASMAA members participate in nationwide associations like the Water Environment Federation and National Association of Flood and Stormwater Management Agencies.

Why Does BASMAA Work?

In this day of less government and more local control, why does a new regional organization like BASMAA work? BASMAA works because it is the right kind of regional alliance.

- It is voluntarily designed, developed, funded, and staffed by local governments. It is made from the bottom-up, not the top-down.

- It is only as strong as the local governments decide it should be and as their participation will make it.

- It supplements the local government programs, it does not duplicate them.

- Its existence depends on the local governments.

BASMAA also works because its design and way of operating are attractive to local governments.

- Membership is based on voluntary participation in a MOU rather than a permit.

- Local governments can achieve regional power by participating in the alliance and proposing good ideas, rather than by having a large population base or a healthy budget.

- The vast majority of decisions are made by consensus rather than by voting.

- By being inclusive in its membership and by providing a full range of options for participation, it

allows local governments to pool their resources, to produce higher quality products, and in some cases, to do things they can not do separately.

BASMAA as a Model

As part of California's efforts to fulfill the requirements of the 1990 Coastal Zone Management Act amendments, the State convened 10 multi-interest technical advisory committees (TACs) organized by a range of issues related to water quality management including urban runoff, irrigated agriculture, pesticide management, rangelands, abandoned mines, and confined animal facilities. Each of the TACs produced a report including recommendations for the State to use in developing its coastal nonpoint source pollution control plan. The common themes in those TAC reports were:

- Volunteer cooperation.
- Public education.
- Management on a watershed scale.
- Technical assistance.
- Agency coordination.

California in turn has made a commitment to using a watershed approach in managing and protecting the State's water resources. A model alliance such as the Bay Area Stormwater Management Agencies Association is an example of how these themes can be implemented as part of watershed protection, and how we can move ahead together.

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Integrated Resource Management-Achieving Multiple Benefits for the Same Dollar

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Introduction

Water is the priceless fuel that powers the California economy, and intense competition for water has long been a part of California's colorful history. Dramatic early battles over water rights have even made their way into popular film and legend. Zealous competition for water is still prevalent today, but its emphasis has evolved from a standoff between clearly opposing factions to a complex struggle among entities whose best interests are far more interrelated than at any time in the past.

Typically, three equally important interests vie for water in California: agriculture, urban entities and the environment. Each has specific water needs, or demands, that are often divergent from one another, and have made it difficult for these groups to mutually agree on water management solutions. (Figure 1).

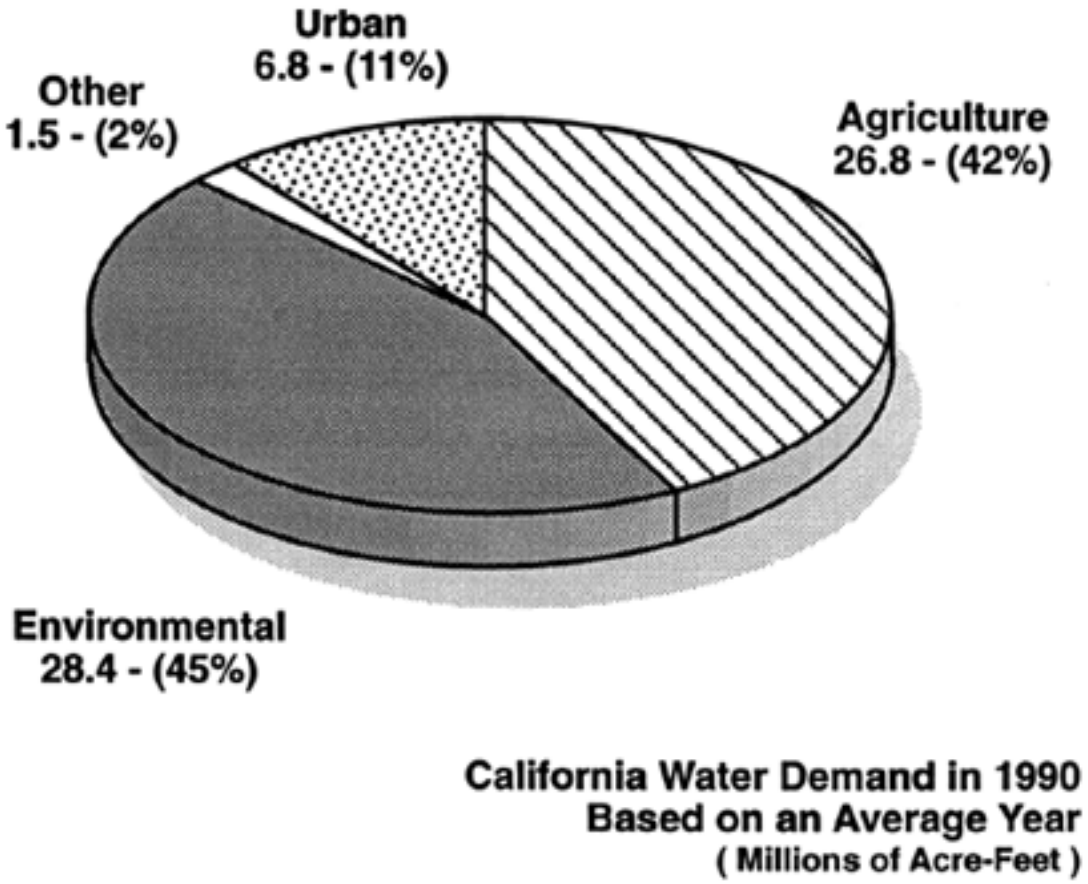

Figure 1.

Today, pressures from increased population, changes in social values, and higher prioritization of environmental needs are causing people to rethink the way California manages its water resources. Many have perceived this shift as a threat to the state's world-renowned agricultural economy and its related industries which are so dependent on access to its water supply. However, more and more, traditionally competing interests are starting to understand and accept their social and economic interdependence on common resources. The process of Integrated Resource Management helps bring to light the many ways these relationships, once viewed as conflicting, can be seen as mutually supporting. Its goal is to see everyone benefit.

Integrated Resource Management

Integrated Resource Management, or IRM, is disproving the long-held view that agriculture, wildlife habitat, urban needs, and water management are incompatible with one another when tied to a single project. The basis of the IRM project model is cooperative problem-solving coupled with strategic optimization of regional resources. Essentially, it makes everything work smarter.

The process brings together representatives from diverse groups within each community or region (agricultural, environmental, urban, and rural officials, federal, state and local agencies and technical experts) to identify, discuss and resolve issues in a way that benefits all parties.

During the IRM process, illustrated in Figure 2, each project area's specific resources and stakeholder interests are considered as they relate to often seemingly divergent project goals. The focus is on resolving multiple issues within a project area, not on simply solving a single problem. This is done by fostering partnerships among traditionally competing interests to find opportunities for conjunctive use solutions. Seeking such opportunities allows all interests to be considered equally and enables as many goals to be met in one project area as possible. And it achieves these mutually beneficial solutions for the same dollar.

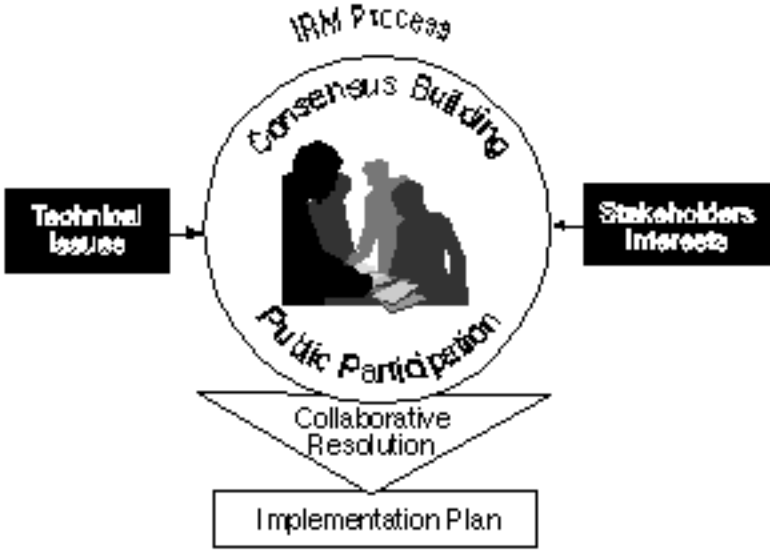

Figure 2.

IRM is an extremely versatile approach that can be applied to many types of situations-local and regional projects, feasibility studies, selection of demonstration projects, and project priority plans. It is also a highly effective project development tool for establishing what can be realistically accomplished. The IRM process thoroughly considers the interests and priorities of the project area's diverse stakeholders, evaluates technical, environmental, and social restraints, explores costs of various strategies, and researches funding options. This information is used to make informed decisions and develop an action plan and strategy based on those parameters that result in implementable projects.

Using IRM, local leadership can enhance agricultural and urban economics by developing solutions that sustain and recover land and water resources for use by future generations. This paper describes how the IRM approach has been used to successfully address technical, stakeholder and community issues in various California projects.

IRM Projects

Towards The Year 2020: Sustaining Southern California's Water Supply

The Metropolitan Water District of Southern California (MWD) provides approximately 3.5-4.0 million

acre-feet per year of potable water to 15 million people and is one of the world's largest agencies. The agency's water needs are primarily met with imported water from Northern California and from the Colorado River. Other sources include groundwater, water reclamation, impounded surface water and a little desalinized water. By the year 2020, the projected population of the South Coast Region of the state will be approximately 25 million people with an estimated water demand of 5.5-6.0 million acre-feet per year. Using IRM, policy makers and professionals representing numerous water agencies joined with environmental, business, and agricultural communities to coordinate an acceptable and affordable level of water reliability for the region through the year 2020.

California's Central Valley: The Crossroads of Agriculture, Urban Life, and Wildlife Habitat

Though predominately an agricultural area, California's Central Valley is also a key stopover point for millions of migrating waterfowl along the Pacific Flyway. It is also home to a growing urban population that was estimated at 5 million in 1990 and is projected to be 10.8 million by the year 2020.

Historically, the Central Valley was made up of nearly 4.9 million acres of wetland and riparian habitat. Over time, with increasing agricultural and urban development, the available habitat declined to what it is today-about 400,000 acres, an 82% drop from historic levels.

Urban development is also displacing farmland in the region at a rate of approximately 6,000 to 7,000 acres per year, and remaining farmers are facing stiff competition for available water from the increasing population as well as greater environmental needs. Such conflicting demands are daily realities for the Kaweah Delta Water Conservation District and the Colusa Basin Drainage District. To find workable solutions for all concerned, both Districts turned to IRM.

Kaweah River Delta Corridor Enhancement Study. The Kaweah Delta Water Conservation District, the County of Tulare and the City of Visalia, are jointly participating in a two-phase Kaweah River Delta Corridor Enhancement Study. The purpose of the study is to select and developed a long-term solution for groundwater recharge, flood control and native habitat conservation and restoration along the Kaweah River Delta corridor.

The study area consists of approximately 23,000 acres and lies on the east side of the central San Joaquin Valley, just downstream of Terminous Dam which impounds Lake Kaweah. It is located between the St. Johns River on the north and Kaweah River (and associated distributaries) on the south, and extends west to the City of Visalia Urban Area Boundary. The land use in the project area is agricultural. Significant remnants of the Valley Oak Riparian forest-unique in the San Joaquin Valley-are found along the waterways in the area. The forest is also an important wildlife habitat.

Phase I of the study is complete. It investigated the feasibility of suitable sites along the river corridor to meet the multi-use objectives of groundwater recharge, flood protection, and habitat restoration. Phase I was conducted in two parts: a reconnaissance level water resources investigation of the potential for

groundwater recharge and stormwater protection, and estimated costs of facilities, and an environmental habitat analysis. Twenty alternative sites were identified. Fourteen were determined to have potential water resources benefits and all twenty had potential environmental habitat benefits. The final report recommended further investigation on six sites.

Phase II, now in progress, consists of an in-depth evaluation of the hydrological and hydrogeological issues regarding each of the six sites, as well as environmental concerns, with special emphasis on meeting the requirements of the Endangered Species Act through the development of a "Safe Harbor" program. The objective of this phase is to finalize the implementation plan to integrate groundwater recharge, flood protection and habitat restoration into a series of facilities along the Kaweah River Delta. Phase II will culminate with a demonstration project which will serve as a model for future facilities along the river corridor. Completion of the demonstration project is scheduled for the fall of 1996.

Colusa Basin Drainage District: Watershed Priority Ranking Assessment Study. The Colusa Basin Drainage District was initially formed to manage problems associated with flood control, drainage and land subsidence within its 650,000 acres of valley land on the western side of the Sacramento Valley. The study area lies west of the Sacramento River, south of the community of Orland, north of the City of Woodland and east of the foothills of the Coast Range of Mountains.

The project objectives involved the priority ranking of 13 watersheds to define areas that are most feasible to achieve the District's goals to: 1) preserve agricultural production; 2) capture surface or stormwater for conservation, conjunctive use and increased water supplies; 3) provide flood and drainage water protection for urban and agricultural interest; 4) assist in groundwater recharge efforts to alleviate overdraft and land subsidence; 5) improve/enhance opportunities for wetland and riparian habitats; and 6) improve water quality. To meet these goals, the District is exploring new ways to put water resources to work that will benefit as many end users as possible

As part of this effort, the District developed an innovative water management program that will provide opportunities for future conjunctive use of water resources to meet the diverse needs of agricultural, urban, and wildlife interests in the Colusa Basin. To launch the program, the District completed in November 1994 a reconnaissance level study entitled the "Watershed Priority Ranking Assessment Study" to (1) determine if the goals could be feasibly met in a conjunctive use manner, and (2) recommend and prioritize areas in which potential projects would provide the most benefit to residents in the District. This study ranked the 13 watersheds based primarily on three criteria: 1) approximate water resource management needs, such as flood control, agricultural irrigation, urban water supply, enhancing wildlife habitat and water resources within each watershed; 2) approximate acreage of land where existing data indicate that conditions are favorable for supporting each of the six principal goals; and 3) willingness of landowners to participate in the project. Results of the ranking identified three watersheds with high potential for implementing conjunctive use projects to meet the District's goals.

The District has identified demonstration project sites within these three watersheds, along with the potential costs and benefits associated with their design and implementation. Implementation includes a feasibility-level analysis of the hydrologic, hydrogeologic, geophysical, and natural resource elements,

the facility options and operations, and a cost-benefit analysis.

As part of the project, a task force of project stakeholders participated in a series of interactive decision-making workshops to identify and discuss primary issues to be resolved through the program related to flooding, protection of agricultural land, urban needs, groundwater supplies, water quality, and wildlife habitat. Public input and participation were also essential in developing the program.

Partnership for the San Pablo Baylands

The San Francisco Bay is the largest estuarine environment on the west coast of the United States and is the primary drainage of California's vast Central Valley. This estuary is also home to nearly 7 million people. The San Francisco Regional Water Quality Control Board is embarking on a two year study of the San Pablo Baylands using IRM principals to restore, enhance, and manage agriculture lands and wildlife habitat in the region. The San Pablo Baylands, which is located in the northern part of the estuary, spans four counties and consists of approximately 37,000 acres of primarily agricultural land, which is ringed by urban and industrial centers. The project is called, "Partnership for the San Pablo Baylands," and includes a host of stakeholders representing private landowners (agriculture, wineries), agencies (local, state, federal), public interests groups (Save San Francisco Bay, Sierra Club, Ducks Unlimited, etc), various business organizations (Pacific Gas & Electric Company, Western States Petroleum Association), and others.

The project has three main goals: 1) to galvanize grassroots support for Baylands protection by undertaking an aggressive public education campaign; 2) to build a partnership among landowners, citizens, and government agencies to create and adopt a collaborative plan to protect, enhance, and restore the San Pablo Baylands; and 3) to establish the foundation for an ongoing program to ensure implementation of the enhancement and restoration program.

To meet these goals, two major initiatives are being undertaken concurrently to build the program. The first is The Partnership Campaign which is the public information, outreach, and education arm of the program and consists of events and activities aimed at building public support for the Baylands. Activities include video production, regional special events, festivals (harvest and flyway festivals), regional tours, quarterly newsletters, and other opportunities for community involvement.

The second is development and implementation of the "Stewardship Plan," which will be a collaborative effort of stakeholders in the project area. This Plan will identify potential sites for enhancing wildlife habitat (wetlands and riparian ecosystems) and for integrating these habitats into existing agricultural and urban land uses. It will also include a regional implementation strategy, developed by the stakeholders, that allows them to implement projects that reflect their long-term vision for the resources in the San Francisco Baylands.

The Plan will incorporate a reconnaissance-level analysis of various technical, cultural, social, biological, and economic/cost-benefit issues associated with the development of wildlife habitats. Managing this

information is a key component in aiding effective group decision-making and creating an workable Plan. One of the selected wildlife habitat sites will be implemented as a demonstration project for the program.

Summary

The ongoing success of these types of projects depends on the active participation and creative input of stakeholders and their desire to see tangible progress. The IRM approach of involving all stakeholders in every phase of a plan's development will result in a plan that is mutually beneficial to all parties and ensures the broadest possible support for the plan's eventual implementation.

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Diverse Partners with One Vision: The Bear Creek Watershed Restoration Plan

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If complicated environmental problems are to be successfully addressed, diverse partnerships must be developed, which are flexible, aggressive, and unified in seeking solutions. Government down-sizing and shrinking budgets require that we make the best use of available resources.

The Natural Resources Conservation Service in Tennessee is the coordinating agency for remediation planning for an Appalachian watershed impacted by acidic mine drainage from abandoned coal mines. Acid mine drainage affects the 14,900 acre watershed and surrounding area, and its effects ripple through the region and nation. Poor water quality from the abandoned mine lands affects the:

- Health and safety of residents and visitors,
- Economic development,
- Recreational opportunities,
- Land use,
- Tourism,
- Educational opportunities,
- Cultural resources,
- Open space quality,
- Aquatic and terrestrial life,
- Biodiversity,
- Endangered species, and
- Soil quality.

In addition, the Big South Fork National River and Recreation Area (BSFNRRA), the South Fork Cumberland River (a state scenic river), and unique geological and scenic areas are diminished in value by the water's impairment.

Acidic drainage from 600 acres of abandoned surface mines and numerous deep mines in Tennessee have rendered Bear Creek in Scott County, TN, and McCreary County, KY, lifeless. According to residents, all fish in the creek died after the initial opening of deep mines in the early 1900s.

The drainage has devastating effects on the South Fork of the Cumberland River (its receiving water) within the Big South Fork National River and Recreation Area. This stretch of the river is designated as a Kentucky Wild and Scenic River. Three endangered and 19 other mussel species are found upstream of Bear Creek in the Cumberland River. No mussels are found downstream although suitable habitat is available.

Heavy metals found in the low pH water (pH 2-5) include iron, lead, aluminum, chromium, nickel, zinc, manganese, arsenic, and copper. Sulfates, acidity, and conductivity are high while alkalinity is low. Sediment and coal fines are found in all waterways.

The impacts from Bear Creek reach a far greater number of people than the 66 residents of the watershed. This out-of-the way location lends its external beauty to the eye of many park visitors seeking refuge from busy daily routines.

However, underneath the landscape canopy are the painful reminders of serious environmental problems.

A $1 million dollar horse camp facility was recently constructed by the National Park Service in the lower watershed with trails leading along and crossing Bear Creek. This stream is not posted and visual appearance does not reveal the threats to humans or horses. Livestock watering, swimming, and other contact sports are often pursued along this seemingly "pristine" stream. However, appearances are deceiving.

Health risks associated with concentrated consumption and water contact are increasing. With new access roads appearing throughout the area, recreational activities in the Bear Creek watershed are escalating.

As a result of the far-reaching impacts and diversified concerns, an initial partnership was formed between the Scott County Soil Conservation District, City of Oneida, TN, Scott County Commission, Natural Resources Conservation Service, and National Park Service.

The technical expertise, methodologies, and historical information needed to assess, fund, and remediate acid mine drainage are not available within any one agency or group. Therefore, a cooperative network was a necessity.

The original partnership began to expand through active solicitation of other groups and individuals directly, or indirectly, affected by the poor water quality. Agencies and individuals were recruited for their leadership roles and most current technology in assessing and remediating acid mine drainage.

A holistic approach was used to unite partners to address their individual goals and concerns. All partners agree that environmental, social, and economic opportunities will be stimulated if Bear Creek's waters can be improved to support life.

The most influential, and necessary, partners are the watershed residents/landowners, local government, and the BSFNRRA supporters. Public meetings and workshops were held in the community to fully explore the concerns of landowners and interested stakeholders. An informational photo exhibit was displayed in highly visible businesses and institutions to heighten public awareness. A companion brochure generated understanding of the study while stressing far-reaching, and little known, impacts to the community.

A delicate and complex web of factors greatly influence perceptions and local decision-making processes. These include:

- Demography of the area,
- Social value system,
- Time/generation,
- Psychology,
- Political distribution,
- Economic status of the watershed,
- Community's willingness to pay, and
- Local objectives and goals.

Community pride and involvement are fostered through keeping the public informed, maintaining high visibility, and showing respect for local culture. This is essential in gaining the confidence and cooperation of local citizens!

An effort was made to visit 100 percent of the watershed residents and talk with as many other local people as possible during our field work. Local people are extremely knowledgeable in locating problem areas providing historical insight. Using local input, a degradation timeline can be constructed which will help determine priority sites and those that contribute most degradation.

The Bear Creek partnership is made up of members from federal, state, and local governments, watershed residents and landowners, conservation groups, and universities. Presently, we have 16 core planning team members and over 30 active partners. Despite its large membership, unity prevails within this group.

Each individual member brings a different perspective and expertise to the project. The partnership

works because as individuals we:

- Share a common goal,
- Maintain individual objectives,
- Take informed professional risks,
- View goals from a broad perspective,
- Respect our similarities and differences, and
- Practice patience!

Positive team attributes are fostered by:

- Open and frequent communication,
- Informal team meetings,
- Close professional, and often after-hours, associations,
- Flexible team leadership, and
- A strong desire to learn from one another.

Already we are seeing the results of our work. The State of Tennessee has installed 3 anoxic drains and 9 constructed wetland cells to treat the acidic mine drainage. A county soil survey has been funded. Two educational videos have been produced. A ground-water map of the portion of the watershed in the BSFNRRA is being constructed that will fill in the remainder of the Recreational Area that presently doesn't have mapping.

Bringing life back to Bear Creek binds our group. Good water quality will bring life back to the landscape. Thoughtful resource management will ensure a constructive future for this valuable resource and all who benefit from its return.

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Using Formative Evaluation Strategies to Involve Landowners in Watershed Protection Planning

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Local citizen involvement in water resources conservation strategies has become all but a given requirement of successful program planning (see, for example, McMullin and Nielsen, 1991; Carroll and Hendrix, 1992; Gericke and Sullivan, 1993). Citizen participation in policy decision making overall has emerged as a major consideration in public life (cf. Langton, 1978). Some authors have suggested increased use of survey research and other social science tools to accelerate and improve the public input process (Wellman and Fahmy, 1985; Kathlene and Martin, 1991; Hale, 1993), and that the more traditional process including public hearings narrow the range of opinion that impact eventual policy. A more recent call has been for public involvement to begin as early as possible in the planning process, potentially including such participation in the design of information and education strategies for particular projects (Anderson and O'Keefe, 1993; White, Nair and Ascroft, 1994). Unfortunately, following through on these recommendations has been slow to come, especially in watershed-related conservation efforts. This case study demonstrates one strategy for more effectively using social science research techniques to build public involvement in watershed programs.

The project attempted to more effectively bring landowners into the early stages of the planning process for the Pensaukee and Honey and Sugar Creeks Priority Watershed Projects in Wisconsin. The Wisconsin Department of Natural Resources recognizes that the success of its Nonpoint Source Program depends upon productive interaction and cooperation with the citizens who are most impacted by the program. The farmers and other landowners who will most likely adopt remedial actions to protect ground and surface waters are those who participate in:

- Identifying the water quality problems confronting them;

- Creating appropriate and viable solutions consistent with local conditions and contexts; and
- Designing ways of adopting those solutions that are equitable to themselves and their communities.

Specific objectives of this project include:

- Using survey and focus group techniques to bring landowners' perspectives to the watershed planning table more quickly (i.e., earlier in the process), and with greater accuracy;
- Using those techniques as a communication medium to get word of the watershed program into the community, and in a way that suggests and encourages citizen interaction, scrutiny and participation;
- More traditionally, providing an assessment of landowners' knowledge, attitudes and behaviors with respect to water quality issues in order to allow development of
- Effective information and education programs that aid landowners in identifying pollution problems and adopting remedial solutions;
- A benchmark for later evaluation of the progress watershed programs.

This pilot project examines landowner assessments of water quality-related issues in the two watershed projects. Survey and focus group research methods are used to determine landowners':

- Perceptions of area water quality problems
- Views on water pollution causes
- Sources of information about water quality issues
- Interest in water quality protection practices
- Attitudes toward potential protection practices
- Willingness to participate in such practices

Methods

This project used both survey and focus group research techniques. The goal of the surveys was to provide a representative overview of watershed area landowner perceptions, attitudes and behaviors. The

strength of the survey is in examining large-enough numbers of landowners to get a broad-based overview of their views and activities. The goal of the focus groups was to interview in greater depth small groups of landowners as to why they held certain views and acted as they did. The focus group findings can't be generalized across landowners, but can allow more extensive expression of subtle and perhaps emotional viewpoints.

The populations examined included all watershed landowners holding five acres or more, based upon lists provided by the County Land Conservation Offices. The Honey and Sugar Creeks population totaled 616, and the Pensaukee 1027, including farmers and nonfarmers. The survey interview base was the entire population of these landowners. Telephone interviews were conducted by UW Extension's Wisconsin Survey Research Laboratory (WSRL) during May and early June 1995, yielding a 57% cooperation rate for the Honey-Sugar and 46% for the Pensaukee. We regard these rates as highly respectable, given the narrow population base available. Two focus group interviews were conducted by WSRL in May and June 1995 for each watershed, examining farmers, nonfarmers, and lakefront property owners in particular.

Findings

- Most landowners in the watersheds believed their wells to be free of serious pollution problems, although a third called their wells at least slightly polluted. Nearly 3/4 had their wells tested over the previous five years, primarily for bacteria. Nearly a third of the property owners called area lakes and streams at least somewhat polluted, with another fifth saying they weren't sure how polluted they were.

- Farm owners believed that whatever pollution does exist results from a range of farm and non-farm related causes. They cited factors they can't control (e.g., heavy rain) as often as those they can (e.g., pesticide use). This may make it less likely that they'll adopt farm-specific remedies to pollution. Nonfarmers put more of the blame for pollution on both agricultural and non-farm pollution causes.

- Farm magazines and newspapers were farmers' most frequently used source of information about water quality and other conservation-related practices,followed by other farmers, family and friends, broadcast farm media, and the County Land Conservation Office. Nonfarmers relied more on general news media, family and friends, and the DNR.

- Interest in water quality protection practices ran high for farmers and nonfarmers alike. Most farmers appeared aware of current conservation practices, although not always by their common names. Just over half said they used conservation tillage, and about a quarter of them or fewer used manure crediting, crop scouting, streambank buffers or pesticide mixing facilities.

- Farmers were split over allowing conservation easements on their land if compensated, although river and streamside buffer zones were somewhat more popular.with 44% saying they would

consider allowing them and 46% saying they would not. Only 11% of farmers were planning to reduce their operations over the next five years, and nearly half said land development was a factor in their decisions. A small minority of farmers said tax credits would influence their decision to reduce in size.

- Over half of nonfarmers said they would be very likely to recycle used oil and limit lawn chemicals use, but fewer were as enthusiastic about eliminating lawn chemical use, sweeping yard waste from street sides, composting leaves and grass, or attending public meetings on water quality protection.

- Almost half of those interviewed had heard of the Honey and Sugar Creeks Priority Watershed Project, and nearly 2/3 said they would be willing to talk to someone from their County Land Conservation Department about practices that reduce runoff pollution.

Recommendations

The following recommendations apply to many kinds of water quality conservation programs, but have particular significance here given the above findings.

A. Look for general trends, but recognize differences

Surveys and focus groups tend to try to locate similarities and general trends within populations such as this one. Priority Watershed Project planners would do well to use these data to look for differences within the population as well. These landowners are in many ways telling us that they are not a homogeneous mass, and that a "one size fits all" approach to protecting water quality will not work for them. These findings should be assessed and integrated with planners' own experiences to develop greater understanding of and interaction with the numerous groups existing within these areas.

B. Keep listening and interacting

Planning an information and education program should include continuous assessment of the needs and capabilities of various constituent groups. This is particularly true given the relatively high priority watershed landowners place on other people like themselves as information sources.

Working with citizens to determine their information needs is likely to be more successful than "targeting" groups to get them to listen to what the information planners alone may believe relevant. While formal surveys and focus groups may be too time consuming and expensive, consider a continuous informal data-gathering or listening process that can include meeting with neighbors to discuss a brochure idea, bouncing field day tactics off of farmers at a breakfast, or calling small numbers of landowners at random to discuss what they think about the program so far. Generalizing too much from such input is risky, but it does keep the program physically in touch with its constituents.

C. Share the knowledge

Increased and continuing dialogue with area property owners may be well served by sharing with them the results of this study. This "information brokering" activity is at the least likely to attract more attention to the project, and serve the useful purpose of letting residents see where they stand with respect to their neighbors. It should also promote media coverage and personal discussion of the topics covered, and likely provide increased feedback to project planners. The surveys have already engaged half of the large landowners in the counties in a discussion of key aspects of the watersheds. This should set the stage for continuing communication at several levels.

D. Build on existing landowner interests

Build on the high interest in water protection to develop greater landowner knowledge of remedial purposes and applications. Interest in water resource conservation appears higher than knowledge_and certainly use of_specific remedial practices and technologies. Information and education approaches can emphasize information about factors such as the expense of practices, their ease or difficulty of use, practicality, risk, profitability and impact on water quality. Try to tie these factors to individual land or farmstead situations to the extent possible. Openly present negatives as well as positives, and address barriers that landowners might see to implementing certain practices. One goal is to act as an objective information broker in helping landowners decide how appropriate a particular practice might be for their situations.

E. Use multiple information channels

These landowners, like most, use a wide array of information channels. Designing an information and education program around only one channel or medium is unlikely to accomplish increased awareness, information gain, attitude formation and change, and taking of action.. Rather, regard these as different stages that need to be advanced by differing media and message strategies. This study and others have shown farm magazines and newspapers to be the most heavily used source by farmers for much if not most technical information about farming operations. Previous research also suggests that in making decisions about changing practices, farmers learn of new practices from farm media, but are often more likely to consult more personal sources_such as county or state agents, and especially other farmers_before actually trying out something new. Nonfarmers may benefit from a similar approach, although in many instances the costs and risks these property owners incur in adopting practices is considerably less than that for farmers. Use of news media, direct mail, and similar promotional activities may have more of a direct payoff with these publics.

F. Keep it personal

Personal one-on-one communication will likely be the most successful avenue for promoting change.

This includes to the extent possible individual and small group meetings with landowners, but also suggests building good relationships with area farm and community leaders, and with key media personnel.

G. Develop measurable goals

Delineate clear, specific and measurable information and education program goals at the outset. This study may provide a baseline for later change in the components examined_problem definition, perceived causes, information use, interest in practices, and actions taken. Rather than focusing only on the end result of actions taken as a measure of success, consider all of the steps in progression. Evaluation should not just be done at the end to determine whether the total effort succeeded, but along the way to allow for changes and adjustments in course.

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One Size Does Not Fit All: Storm Water is a Bigger Issue since Local Communities have No Regulatory Requirements through CSO Controls

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Increased budgetary pressures coupled with new congressional guidance has caused the regulatory agencies to re-evaluate the ways in which they manage water resources. Sheer necessity has lead to inter- and intra-governmental coordination between federal and state agencies and local units of government; public/private partnerships with the regulated community; and public outreach and education. The Rouge River National Wet Weather Demonstration Project (Rouge Project) has recognized this shift in the regulatory process and has stepped forward to work with the regulatory agencies to focus not only on water quality management but also on other media such as contaminated sites, air deposition and contaminated sediments. This paper summarizes the progress to date.

The Rouge Project began as a response to concerns over combined sewer overflows. However, Wayne

County, Michigan quickly recognized that without the control at other pollutant inputs, the millions of dollars that would be spent on combined sewer overflow control would not result in attainment of water quality standards, that is restoration of impaired use. Therefore, the Rouge Project is addressing pollution sources to the Rouge River from nonpoint sources as well as combined sewer overflows.

The Rouge Project is exploring ways to integrate the various federal, state, and local statutes and regulations to improve water quality in the Rouge River. It also will attempt to identify the gaps and/or barriers inherent in those regulatory frameworks and recommend strategies to overcome them. The goal is to comprehensively protect a watershed that covers multiple political jurisdictions and is threatened by a wide range of pollutant sources. To achieve this goal, the Rouge Project has undertaken efforts to:

- Assist in improving the capability of regional, state, and local agencies to address broad programs that affect one of more traditional environmental problems.
- Identify programs that affect resource protection within the watershed.
- Demonstrate existing and proposed interrelationships among program areas.
- Identify difficulties and opportunities in integrating programs.
- Increase awareness of new regulations, enforcement authorities, technical guidance, and other information affecting environmental management.

This paper will present examples of successful cooperation between programs and levels of government, successful efforts to fill the gaps between environmental statutes and regulations, and highlight institutional barriers that hinder efforts to manage a resource rather than manage specific pollution sources.

The mood of the Country is usually reflected in the political system and this political system generally drives the regulations which impact all of our lives. This was true in the late sixties when the public demanded an improvement of the environment and it is true today. But to quote the 1960's poet laureate, Bob Dylan, "The times they are a changin."

Many contend that these changes are bad and that water quality will certainly suffer. The authors of this paper are more optimistic but recognize fully that the easy work has been completed and now the hard work must be tackled. We also recognize that our jobs have changed forever and the longer we wring our hands and wish for "the good old days", the longer we delay achieving the goals of the Clean Water Act. We are after fishable and swimmable waters_nothing more and nothing less. The ways to get there are very different than first envisioned. Command and control took us through most of our journey but now we realize the road to high quality water goes through the Council Chambers.

Background

The Rouge River has exhibited extremely poor water quality for decades. The River drains 427 square mile of Southeast Michigan including a major portion of the city of Detroit. The mouth of the Rouge is both the birthplace of the Automotive industry and the roots of the arsenal of the free world. While many of the factories which provided trucks and tanks and planes through two World Wars remain, many only exist as abandoned reminders of past glories. Thus the stresses on the Rouge River go beyond the typical water quality problems facing most urban rivers. These special problems aside, the river is unlikely to obtain the goal of fishable and swimmable under existing regulation. The Rouge River National Wet Weather Demonstration Project (Rouge Project) presents an alternative strategy to address the water quality problems of the Rouge River which is less costly than the existing (and proposed) regulations and is more likely to succeed.

Command and Control

The introduction of the Clean Water Act of 1972 (PL 92-500) and the National Pollutant Discharge Elimination System (NPDES) program did much to control point sources of pollution throughout the watershed. Unfortunately many of the gains realized through point source control were offset by the growing non point loads resulting from uncontrolled urban sprawl. As the downstream communities wrestle with financing combined sewer overflow(CSO) control many are beginning to ask what level of control is appropriate for a river which will see little or no change in use. This question of equity is further shaded by the fact that the down stream communities are often older, generally less affluent, and made up of a much higher minority constituency. Is it just to ask these communities to finance major CSO control projects with little change in their ability to use the river while the more affluent suburban communities are allowed to continue to transfer significant levels of pollution to their downstream neighbors?

Command and control was extremely successful and we should all be proud of the accomplishments our country has achieved over the past twenty-five years. Unfortunately, it became impractical to control the multitude of nonpoint sources which contributed to degradation of our lakes and streams. Basically, there could never be enough "environmental cops" to enforce the environmental regulations at each township, subdivision or industrial site. Other pollutant sources which had no apparent owner remained on lists for years but little or no action resulted. Abandoned dumps and contaminated sediments remain a vexing problem in most urban watersheds. Thus, it seems that the strengths of the Clean Water Act should be retained while we look to new ways of solving the problem we cannot seem to overcome.

This reasoning would suggest a continuance of the NPDES program for point sources while re-evaluating the current approach for storm water control, abandoned dump remediation, and contaminated sediment removal.

The Rouge Project is based on the premise that all pollution contributors are willing to address their own pollution sources but are more likely to act if it is clear that their neighbors are acting. Our recent work with the regulatory agencies, local communities, industries, environmental groups, small business

persons, and the general public has demonstrated that all are willing to take the next step in water quality management. The step beyond command and control.

We believe the flexibility provided through the United States Environmental Protection Agency (USEPA) "Project XL" program is precisely the ingredient needed to allow all stakeholders to focus their limited resources on projects that achieve real water quality improvement rather than mere regulatory compliance.

Consensus Based Water Quality Improvements

Many in the regulatory agencies have verbally supported the end of command and control but have missed an obvious extension of this premise: consensus based water quality programs are largely voluntary. This is a very foreign concept to most regulators. Stated simply, command and control is administratively seductive. Often programs which begin as consensus based projects degrade into the old "comply or die" means of problem solving. It is precisely this tendency which often prevents local units of governments (and most industries) from mitigating environmental problems on their own. Basically, it appears that most local units of governments don't trust state and federal regulators. Oddly enough, however, this is in direct conflict with the general public. Surveys of Rouge River residents confirm that the residents place extremely high trust in the Michigan Department of Environmental Quality and the United States Environmental Protection Agency and substantially less trust in their locally elected officials.

Any consensus based water quality improvement program must recognize not only this incongruity but also the forces driving those differences. The local units of government are under increasing pressure to provide more services while lowering taxes. When faced with a decision between a fire truck or a water quality program, the fire truck wins every time. In short, local officials are doing the best they can with what they have available to them. Until they demand additional local programs, few are likely to be initiated. The general public, on the other hand, has generally looked to the state and federal governments to protect their environment. Much of this is driven by their belief that the problems are too large to be handled on the local level. They continue to believe that big business and often their own local governments must be held accountable for their discharges. The public, however, does not recognize that this battle, for the most part, has been won. The battle now has shifted to a large number of smaller problems which are best fought at the local level. The challenge, therefore is to get the local officials and their constituencies to recognize their respective roles and encourage them to step forward.

The Rouge Project has struggled with the conflicts inherent in attempting to implement programs on a watershed basis where the political boundaries do not match the watershed boundaries. To overcome this problem a series of subwatersheds have been identified and individuals from within the local units of governments were asked to lead small working groups which included officials from their neighboring communities. While the Rouge Program Office provided a detailed menu of possible projects, it is these officials who will determine the actual components of their storm water management program. This has some inherent strengths and weaknesses. Obviously the local officials have the best understanding of the

problems facing the local communities. It is equally obvious that each subwatershed will have different programs to address the various problems. Thus the challenge will be to integrate these collective programs in an equitable manner.

It is envisioned that there will be some baseline components which will be required for each local community to participate in the strategy. These may include a storm water ordinance or a commitment for funding and design standards for both new construction and reconstruction. The remedial efforts, however, will be site specific. Each watershed and each community have different environmental problems. Prioritizing these problems requires that technical information documenting the environmental concern be presented to the local stakeholder in a manner in which they can evaluate the risk to themselves and their downstream neighbor. This risk can be a human health concern, a loss of recreational opportunity, or the risk of a regulatory response due to lack of action. When these risks are well understood, the public is usually motivated to respond.

The Rouge Project is trying to gain consensus at a local level to change many of the standard practices in an urban community. This will likely require changes to the master plan, building codes, the subdivision ordinance, road maintenance practice, parks' practices, and a wide range of other small changes to the existing local ordinances. These changes must be driven by a good understanding of the costs and benefits to the general public. Only then will the general public and the local units of government voluntarily move forward on storm water control and the required changes to their ordinances.

One Size Does Not Fit All

A voluntary water quality program will only proceed if the local officials and their constituencies agree on the problem to be solved. These problems (both real and perceived) will vary from reach to reach. The success of a voluntary, consensus based storm water program is easy to measure: is the public willing to pay for the required practices. With this benchmark, the Rouge Project developed a "Strategy to Restore the Rouge River." The goal of the strategy to restore the Rouge River is to cost-effectively manage storm water to restore beneficial uses to the Rouge River through a cooperative effort of the affected communities, state and federal regulators, and other stakeholders in the watershed under the auspices of the Rouge Project.

The strategy is designed to develop a practical approach to reduce water quality impacts of storm water discharges to the Rouge River through the application of watershed-wide management approaches. As part of the strategy and prior to the preparation of the strategic plan, the following activities were initiated:

- A watershed-wide storm water monitoring program was implemented that will efficiently use limited resources to identify problem areas and impacts.

- Demonstration and pilot projects in selected subwatersheds were designed to evaluate the cost effectiveness of alternative approaches to remediate storm water pollution sources and mitigate

the impacts of excessive flows.

- Current legal options were analyzed for managing storm water on the basis of hydrologic or watershed boundaries.

The strategic plan will include:

- Proposed changes in state regulatory and funding assistance programs to create incentives that encourage participation by local communities and other interested stakeholders in cooperative watershed-wide storm water management.

- An implementation schedule with specific target dates for watershed-wide actions to systematically address storm water problems in each subwatershed.

- Estimated costs for implementing the storm water management strategic plan, alternative funding mechanisms, and acceptable institutional arrangement(s) between communities to implement the plan.

A Storm Water Advisory Group made up of local communities periodically convened to review draft status reports on various elements of the strategy. A smaller working group made up of representatives from the Wayne County Department of the Environment (and the Oakland County and Washtenaw County Drain Commission offices depending on the subwatersheds), Michigan Department of Environmental Quality (MDEQ), and local cities and townships directly involved in the selected subwatersheds provided guidance to the Rouge Program Office (RPO) staff in preparing the draft documents and reports that were used in development of the strategic plan.

Specific subwatersheds were identified with working group partners where specific intensive sampling, investigation, and demonstration projects took place to determine who will do the work, sources of funding, expected outcomes, and the target dates for completion of projects.

All subwatersheds in the Rouge system were classified, based on the analysis of information collected for subwatersheds to systematically remediate storm water problems, on a priority basis. The benefits of watershed approaches to storm water management were identified to both the local elected officials and the general public. Specific changes in state policies, regulations, and statutes that would create positive incentives for communities within the Rouge River and elsewhere in Michigan are being investigated. A voluntary, cooperative effort to manage storm water to improve water quality through an integrated watershed-wide approach will be proposed.

Progress in this type of voluntary approach often seems slow. One must be reminded that many of the problems being addressed were first identified in the Clean Water Act Section 208 program. When first challenged with nonpoint source control, the local units of government were justified in deferring their attention until point sources were controlled upstream. Now local officials can readily see their cities

impact on the river. As a result, they seem more willing to work with their local councils, planning commissions and public to address the problems which were easy to ignore twenty years ago.

As different as this process might seem to some, the progress on the Rouge River suggests that this is not only the best way to proceed but it may be the only way to proceed. It will be the hundreds of small projects which will finally attain the original goals of the Clean Water Act.

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The C&SF Project Comprehensive Review Study: Interagency Planning Team Integration

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Introduction

The Central and Southern Florida (C&SF) Project is a multi-purpose water resources project which was built by the Corps of Engineers (Corps) to provide flood control; water supply for municipal, industrial, and agricultural uses; prevention of saltwater intrusion; water supply for Everglades National Park; protection of fish and wildlife resources; and other services to the south Florida area. While the project has served its authorized purposes well, it has also had unintended adverse consequences on the unique Everglades and Florida Bay ecosystems. In 1992, Congress authorized the Corps to undertake a comprehensive review of the C&SF Project to determine the feasibility of modifying the project to restore the south Florida ecosystem while meeting other water-related needs. In June 1993, the Corps began the C&SF Project Comprehensive Review Study. The first phase of the study, the reconnaissance study, was completed in November 1994.

Given the complexity of this task, an interdisciplinary, interagency team was assembled to conduct the study. This paper describes the approach and techniques used to build and develop the study team.

Study Background

The C&SF Project, which was first authorized by Congress in 1948, includes about 1,000 miles each of levees and canals, 150 water control structures, and 16 major pump stations. The project area encompasses approximately 18,000 square miles from Orlando to Florida Bay with at least 11 major physiographic provinces: Everglades, Big Cypress, Lake Okeechobee, Florida Bay, Biscayne Bay,

Florida Reef Tract, nearshore coastal waters, Atlantic Coastal Ridge, Florida Keys, Immokalee Rise, and the Kissimmee River Valley. The Kissimmee River, Lake Okeechobee and the Everglades are the dominant watersheds that connect a mosaic of wetlands, uplands, coastal areas, and marine areas.

As a result of land use and water management practices during the past 100 years in southern Florida, the defining characteristics of the regional wetlands of the south Florida ecosystem either have been lost or have been substantially altered. In recent years, the decline of the Everglades and Florida Bay ecosystems has received national attention. In 1993, the Clinton Administration declared that restoration of the Everglades and Florida Bay ecosystems was one of its highest priorities. A number of restoration efforts are currently underway by federal, state, and local agencies. The purpose of the Review Study is to determine the feasibility of making modifications to the Central and Southern Florida Project to restore the Everglades and Florida Bay ecosystems while providing for other water-related needs.

In past years, gridlock, guarding of turf, and lack of cooperation among agencies was all too common. In order to improve coordination and communication among agencies, an interagency South Florida Ecosystem Restoration Task Force was established in 1993. The Task Force is chaired by the Assistant Secretary of the Department of the Interior. In 1994, Florida Governor Lawton Chiles established the Governor's Commission for a Sustainable South Florida to recommend strategies for ensuring the long-term compatibility of a strong south Florida economy and a healthy south Florida ecosystem, and to improve the coordination of both public and private sector activities. As a result, there is an unprecedented level of cooperation and support among the agencies involved in the restoration effort.

The Need for a Different Approach

The Corps of Engineers, Jacksonville District, was given the responsibility for accomplishing the Review Study. Because of the intense public, political, and media interest in the restoration of the South Florida ecosystem, the process used to accomplish this study was carefully considered. It was important that the study utilize a watershed approach to ensure that the water resources problems of the study area were considered in a holistic fashion. Thus, at the inception of the study, it was recognized that a "not business as usual" approach was needed to successfully manage and accomplish this study.

The study team consisted of an interdisciplinary professional staff from the technical disciplines necessary to accomplish the study. These disciplines included civil engineers, hydraulic engineers, cost engineers, biologists, ecologists, resource managers, community planners, economists, geographic information system specialists, public involvement specialists, real estate specialists, and technicians. Corps team members were drawn from the staff of the Jacksonville District, and were supplemented by other Corps personnel on temporary duty assignments.

Given the complexity of the problems to be considered in this study and the desire to utilize the skills of specialists in other agencies, a multi-agency approach was developed to complete the formation of the study team. Multi-agency staffing was essential in order to facilitate the flow of needed information among agencies, and, more importantly, to achieve buy-in and ownership by the key public agency

stakeholders. This multi-agency approach also fit into the cooperative spirit fostered by the interagency South Florida Ecosystem Restoration Task Force and the Governor's Commission for a Sustainable South Florida. The study team included personnel from other agencies such as the South Florida Water Management District, the National Park Service, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Florida Game and Fresh Water Fish Commission. Team members from these agencies were full participants in the study effort. The participants from the other agencies were funded by their respective agencies. The intent of this approach was to move beyond normal coordination among agencies to interagency integration to enhance the quality of decision making.

How to Build an Interagency Team

The study team began work in July 1993. Study team members were assigned to the study on a dedicated full-time basis under the supervision of the Corps study manager in order to avoid competing priorities with other assignments. In addition, a new organization within the Jacksonville District was created for the purpose of accomplishing the study. Office space for the team was obtained so that team members could work together. Individual work spaces were made fairly small to provide room for a conference area. The conference area included flip charts and marker boards and provided an area where team members could spontaneously get together and brainstorm. As a result, the study benefitted from the synergistic effect caused by this approach. The enhanced intra-team communication greatly supported the technical activities on the study.

The proximity of team members of different disciplines fostered a better and more thorough understanding of technical issues which improved problem solving. For example, over time, the hydrologic engineers became more in tune with the needs of the biologists and the biologists better understood hydrology. As a result, each team member's perspective was broadened. The net result was a team better able to understand the problems they were analyzing and the possible solutions to these problems.

For the first several months, the primary focus of the study effort was on teambuilding and developing the overall "game plan" for the reconnaissance study. During this period, the team met every day. The conference area became the focal point for the team as most of the day was spent in team discussion. After a while, some team members began to feel that too much time was spent in meetings and not enough time was spent individually doing "real" work. However, later on these team members realized that the extensive team meetings were critical to the success of the study. The time spent in team meetings, discussions, and decisions is "real" work too. Videotapes and personality profile instruments were used stimulate self-awareness, improve communication among team members, and foster trust. Humor was extensively used to break tension. The team socialized together. Computer generated banners with slogans summarizing the team approach were used to decorate the office.

Throughout the reconnaissance study, extensive briefings with all team members present were held in the conference area for senior management and other officials. These "around the table" discussions allowed all team members to express their views and to interact closely with senior management. Most

importantly, these meetings resulted in management decisions being communicated directly to the study team rather than just being filtered through the study manager.

Decisions were made by the team as much as possible. This allowed the team to "own" their decisions rather than having decisions and solutions imposed on them. This also greatly increased "buy-in" and reduced the possibility of individuals taking actions on their own that were contrary to the team's. The quality of decision making was enhanced by the synergistic nature inherent in the team approach. In this context, the study manager is a facilitator and motivator. In other words, a leader, not just a manager.

Every Friday morning the team met for "weekly wrap-up." At these sessions team members summarized their activities for the week and also discussed the positives and negatives of the week. A volunteer recorded the discussion on a flipchart. The summaries usually involved review of team meetings, briefings for management, and decisions reached by the team. Weekly wrap-up usually lasted about a half-hour. Following the meeting, the flipchart notes were typed and kept on file by the study manager. The purpose of weekly wrap-up was twofold. First, it provided an opportunity for the team to realize that significant progress was being made each week. In a long study effort, it is sometimes difficult for team members to realize that progress was being made. Weekly wrap-up allowed the team to see small victories happening. Second, it provided an opportunity for the team to discuss how they were working as a group. It also served as an outlet for frustrations that inevitably develop in such an intense effort.

An extensive public involvement program was undertaken as part of the reconnaissance study effort. The first round of public workshops was held six months after the study began. During this time, the team spent almost two weeks on the road together. This experience cemented the relationship that had been building up over the preceding six months.

Current Efforts

The reconnaissance study was completed in November 1994. The Review Study has now moved into the more detailed feasibility phase, which will take a number of years to complete. The interdisciplinary, interagency nature of the study team has been expanded to include a number of additional federal and state agencies. The number of people working on the study has increased greatly and team members are geographically dispersed.

The feasibility phase of the study will require new efforts to integrate this larger dispersed team. Electronic communications such e-mail and the Internet will be extensively used for team members to communicate.

A teambuilding workshop was held in December 1995. A facilitator was brought in for the workshop. Each participant took the Myers-Briggs personality profile which was used for self-awareness and for discussions about how to improve team communication. As a result of the workshop, a partnering charter was developed by the study team and signed by each member. The charter commits the team to maintain a positive partnership/team approach at all levels, establish a general problem-solving process, establish

effective means of communication with and between partner agencies as well as others, and facilitate interagency information exchange.

Conclusions

In solving complex watershed problems such as Everglades restoration, coordination alone is not good enough anymore. Instead, integrated interagency teams are needed. Problem solving benefits from the synergistic approach that integrated teams offer. Initial efforts should focus on teambuilding, even at the expense of "real" work to create an atmosphere of trust that allows individuals to take reasonable risks. Process is important. How one decides to do something often dictates how well it will be done.

Early in the study, team members were constantly reminded that they should "leave their agency hat at the door" and work as a team to develop the best solutions to problems. The message obviously took_one day we all came in to find that each one of us had a hat with the word "agency" embossed in the front. In this way we were truly able to leave our agency hat at the door!

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EPA Reaches Out to Local Governments

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The Environmental Protection Agency (EPA) has long recognized the significance of land use decisions, but has struggled to find ways to address the impacts of these local decisions. In programs like the National Estuary Program, EPA has recognized new opportunities to influence land use planning, and is beginning to focus on them. This paper describes some of those opportunities and the lessons learned from working with local governments through the Delaware Estuary Program (DELEP).

The National Estuary Program (NEP) was established by the Water Quality Act of 1987, section 320. The purpose of the NEP is to identify, protect, and restore estuaries of national significance. The DELEP was nominated as an NEP by the governors of Pennsylvania, New Jersey, and Delaware in 1988. The study area includes the Delaware drainage areas of the three states (Figure 1). In 1989, the Management Conference was convened to oversee development of a Comprehensive Conservation and Management Plan (CCMP), which documents the problems of the estuary, and proposes solutions. The Management Conference includes representatives of federal, state, and local governments; citizen groups; businesses; the scientific community; and resource users.

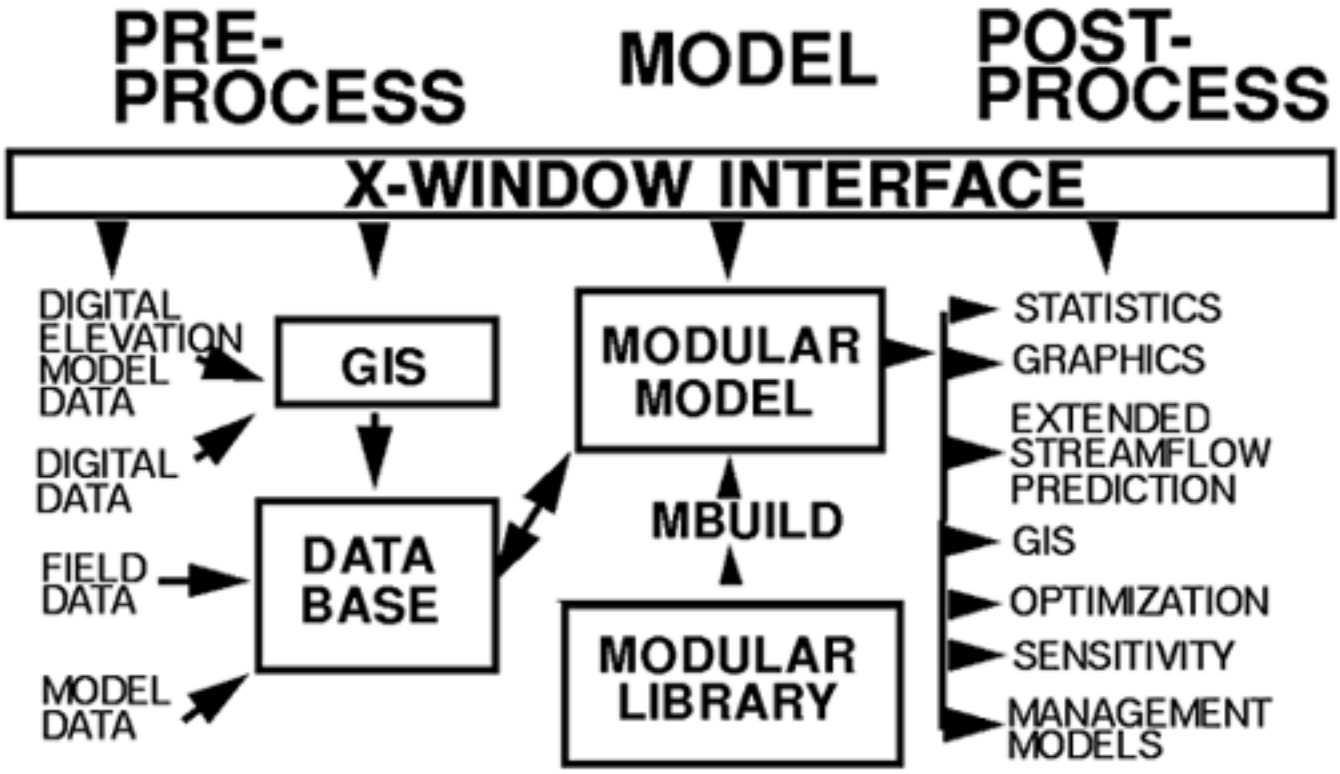

Figure 1. Delaware Estuary Program Study Area.

One of the first tasks of an estuary program is to identify the problems specific to the system. The DELEP went though a process of data analysis, research, and prioritization to identify key problems that require development of action plans. The action plans in the CCMP address land use, toxics, habitat loss, water supply, and environmental education.

The Management Conference members initially resisted identifying land use as a problem. They recognized that water pollution, habitat loss, and air pollution were related to land use patterns, but were reluctant to name the problem "land use," because of the political sensitivity of the issue. Through one long torturous meeting, they debated defining the problem or need as coastal zone management, nonpoint source pollution, or local government assistance; anything but land use. They finally settled on the following problem statement:

The current pattern of land development consumes large amounts of natural habitat and agricultural land, and results in nonpoint source pollution and fragmentation of habitat, with adverse impacts on living resources and water quality.

The DELEP first explored the land use decision process in an inventory and assessment project completed in December 1990. That study revealed that municipalities were the key land use decision makers in the estuary area, and that in Pennsylvania and New Jersey, the counties were only advisory. In New Jersey, counties are slightly more influential than those in Pennsylvania, in that county staff review and approve subdivision plans that affect county roads, and regulate on-site septic systems. Counties in

Pennsylvania and New Jersey do not regulate land use directly. Counties in Delaware have authority over unincorporated areas. Few municipalities in any of the states have full or part-time planning staff. The result is that local land use planning is primarily focused on local issues, and local planners do not have the resources or perspective to consider regional environmental resources. Based on their experience and this information, the Local Government Committee supported the selection of land use as a major issue, even though the federal and state participants were initially reluctant.

Once land use was selected as a priority, a land use task force was established to further define the problem and develop the action plan. The task force considered three approaches: (1) focusing on reducing environmental impacts of land development; (2) providing tools for better land use decision making, such as maps and model ordinances; and (3) improving the process by which land use decisions are made. The draft CCMP includes a land use action plan that addresses all of these issues, and promotes a regional perspective. It also proposes development of a long-range sustainable development strategy.

EPA currently has no direct role in local land use decisions, and probably never will. However, EPA is one of the key partners in the DELEP. To the degree that our mission and interests are embodied in the land use actions that have been included in the DELEP CCMP through a consensus-based decision process, we have an opportunity to participate in implementing them. This paper describes some of the ways EPA can contribute to improving the process of land development and reducing impacts from development.

Staff involvement in the Local Government Committee provided an education in land use planning and decision making and local government issues. An EPA staff member was the lead writer of the land use chapter, working through the long process of consensus building and research with a land use task force and state staff. A temporary EPA staff assignment with the Montgomery County, Pennsylvania, Planning Commission further helped to define opportunities for EPA to influence land use decisions. It also clarified the limitations on the ability of any organization other than municipal governments to influence local land use decisions. Based on this experience, three roles can be identified for EPA.

Training

A variety of excellent training and educational programs on land use and planning issues already are provided by states, counties, nonprofit organizations, and colleges. However many of these programs fail to consider environmental issues, or else they separate environmental issues from other issues important to municipalities, such as transportation, maintenance practices, fiscal policies, and taxation. Also, local officials are inundated with meetings and training opportunities. Rarely are they eager to attend another evening or Saturday meeting. Finally, training needs to extend beyond the traditional audiences of planning commission members to include developers, municipal engineers and solicitors, municipal elected officials, and lenders.

Existing training programs can integrate environmental issues into programs that focus on other

municipal concerns. They can expand their audiences, and they can use alternative delivery modes such as cable programs, taped radio interviews, video programs, newsletters, fact sheets, hands-on design studios, and portable displays. Whenever possible, training should be portable and convenient.

One of the DELEP action plans proposes to develop a regional calendar of ongoing training. This sort of calendar would allow local government officials to take full advantage of existing training opportunities, and allow gaps to be recognized and filled. EPA has committed to take the lead in this effort.

Information and Technical Assistance

The DELEP plan proposes a variety of technical assistance efforts, including access to geographic information systems by local governments, development of self assessment techniques, and support of watershed modelling. Municipalities need data for planning and decision purposes. Historically, the scale of data available to EPA was not detailed enough to be of use to municipalities. With the availability of remote sensing techniques and larger computers, some of our data is sufficiently detailed to be of use to local governments if it is formatted properly. Local governments need to understand the significance of the data and have it transformed into information to help them plan land use and review proposals.

The land use task force of DELEP suggested that habitat maps should indicate appropriate types of development and best management practices. For instance, a map of large forest tracts should recommend cluster development with limited clearing to protect forest canopy. Members of the task force also cautioned that these types of maps would be politically sensitive, and should not delineate zones for development or preservation.

Another area for EPA technical assistance is the link among land use, habitat, water quantity, and water quality. We intuitively know there is such a link, but we need to document it and teach it. We need to understand how much development can be accommodated before streams and wetlands deteriorate, and the water supply runs out. What special measures should be required in sensitive areas? A better understanding of these linkages can support municipal zoning decisions. Developers will challenge municipal zoning decisions if the community does not have a strong scientific basis for the decisions. EPA information can provide such a basis.

Other technical assistance could include research on the economics of cluster development, impacts of open space on land value, and the use of fiscal impact analysis. An EPA staffer working on the DELEP has researched market appreciation of cluster development compared to typical sprawl development. Such information can help support a community's decision to try innovative development patterns.

Using Regulatory and Grant Programs

The DELEP plan proposes to use existing programs to support desired land use patterns in several ways. For instance, state regulations for wastewater treatment systems could encourage alternative systems. Where zoning allows two- or three-acre lots with on-site septic systems, streamlined permitting for small

alternative systems could encourage compact development and preserve open space. EPA can help to encourage these innovations.

Another role for EPA is helping states to develop consistent policies for redevelopment of idle or abandoned industrial sites, known as "brownfields." Developers are reluctant to purchase such properties because of concerns for environmental contamination. EPA is already working on a brownfields initiative to counteract the trend toward development of farmland and abandonment of urban areas. This effort needs to be coordinated with local land use plans.

Other existing EPA programs such as the state revolving funds, National Environmental Policy Act (NEPA) reviews, wetlands, and solid waste affect local land use decisions, but are not integrated into the land use process. As the lead federal agency in the DELEP, EPA can be a model for this kind of integration, and can bring other federal agencies into the process.

Conclusions

EPA's experience in working with DELEP has provided three key lessons in working with local governments on land use issues.

- We must accept that local governments are the key decision makers for land use issues, at least in the Delaware Estuary watershed. Every day, municipalities make decisions to approve turning a farm into a strip mall, or to expand a parking lot by an acre, or to divide one piece of land into two. Most of these decisions are never reviewed at the state, federal, or even the county level. If we want to influence where development goes, we must accept that local governments make those decisions and work with them.

- Local governments will not take our advice just because we are the federal government, or because we are the good guys, or because this is the right thing to do. We must identify where our interests and those of local governments coincide, and work at that intersection. We must build trust and respect local priorities. However, we cannot put relationship-building over our legitimate interests.

- Information and services must be in a form that local governments can use. The decision makers at the local level are usually not professional planners or environmentalists. They are intelligent, committed, concerned volunteers. They need information, but the information needs to be formatted and interpreted to be helpful, not overwhelming. They will use environmental information that is related to their daily concerns. Does preservation of open space provide fiscal benefits? Will compact development reduce traffic congestion? Can best management practices for nonpoint pollution also reduce flooding?

The Delaware Estuary Program, with EPA as a partner, is just beginning this new excursion into land use concerns and the workings of local governments in the Delaware Estuary watershed. Success will depend

on our willingness to accept the lessons learned in the development of the CCMP, and on our commitment to integrate concerns for land use into our programs.

Acronyms

CCMP Comprehensive Conservation and Management Plan

DELEP Delaware Estuary Program

EPA Environmental Protection Agency

NEP National Estuary Program

NEPA National Environmental Policy Act

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University Contribution to Lake and Watershed Management: Case Studies From the Western United States_Lake Tahoe and Pyramid Lake

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Background

The role of universities in the evolving dialogue on watershed management is critical and it is more important than ever that state and federal agencies take advantage of this opportunity. Even though the history of academic involvement in research at the watershed level dates back many decades, it is our belief that the contribution of university expertise in environmental protection is not fully utilized by governmental agencies at all levels. Because universities do not have formal regulatory authority, they often play only a peripheral role in decisions related to environmental policy, such as the management of watersheds. However, research and monitoring efforts by these institutions often provide key information which are cornerstones for (1) understanding ecosystem processes, (2) determining the impacts of anthropogenic stress on environmental health, (3) formulating and evaluating watershed management options, and (4) forecasting long-term consequences of policy decisions on resource sustainability. Too often, scientists who are involved in day-to-day field research have no fixed part in decisions involving

environmental policy, implementation strategies, long-term planning, etc. Especially in light of the unfortunate juxtaposition of budgetary demands to downsize agency staff and expenditures; the increased need to understand the effects of pollution (from the gene to the ecosystem level); and the continued public demand for clean air, land and water, the nation's universities are particularly well positioned to increase their contribution. A better, closer working partnership between university researchers, and federal, state and local regulatory and planning authorities will allow for a much more effective ecological and economical approach to environmental protection and watershed management.

One of the better documented examples of this type of cooperative effort comes from the Tahoe Basin, where investigations by the Tahoe Research Group (TRG) at the University of California-Davis have provided clear evidence for the onset of cultural eutrophication in ultra-oligotrophic Lake Tahoe. Tahoe is world renowned for its clarity and water quality; however, our continuous, long-term evaluation of lake chemistry and biology since the early 1960's has shown that algal production is increasing at a rate greater than 5 percent per year with a concomitant decline of clarity at the alarming rate of 0.5 m per year (Figure 1; Goldman, 1988). In the post-war years, but especially after 1960, the human population in the Tahoe Basin rose significantly; this was accompanied by improvements to the road network and an overall increase in urbanization. TRG investigations during the period 1962-1996 have shown that multiple factors such as the stress of land disturbance, habitat destruction, air pollution, erosion in disturbed watersheds, extensive road network, etc. have all interacted to degrade the Basin's airshed, terrestrial landscape, and streams, as well as the lake itself.

Another example which underscores the importance of comprehensive scientific research and monitoring, and the role to be played by universities in watershed management comes from Pyramid Lake, Nevada a desert lake located at the terminus of the Truckee River. Both lakes are hydrologically linked by the Truckee River, which is the sole outlet from Tahoe and the only permanent inflow to Pyramid. Pyramid Lake is contained within the Pyramid Lake Paiute Reservation and is completely under the jurisdiction of the tribe. Amendments to the Clean Water Act in 1987 authorized the EPA to treat federally recognized tribes as states for certain provisions of the Act. This included establishment of water quality standards for waterbodies on tribal land along with antidegradation and implementation policies. In 1989 we were asked to assist the tribe in development of these standards and policies. Given that (1) the lake and river are important economic and cultural resources to the tribe, (2) the lake is inhabited by threatened (Lahontan cutthroat trout) and endangered (cui-ui sucker) fish species, (3) levels of total dissolved solids (TDS) in the lake have increased to levels which potentially threaten cui-ui survival, and (4) point and nonpoint loads of nutrients from watershed urbanization upstream of tribe lands may affect algal growth and oxygen conditions in the river and lake, the tribe needed to dovetail its regulatory responsibility with a comprehensive scientific program.

Watershed and Lake Descriptions

Lake Tahoe, California-Nevada lies in the crest of the Sierra Nevada at an elevation of 1,898 m. The drainage area is 812 km2 with a lake surface of 501 km2, a ratio of only 1.6. Tahoe is located in a subalpine watershed dominated by coniferous vegetation and nutrient-poor granitic and volcanic soils. A

total of 63 streams flow into the lake. It is the world's tenth deepest lake at 505 m with a mean depth of 313 m. Its volume is 156 km3, with a residence time of about 700 years, and it is ice-free year around. The depth of vertical mixing varies from 100 m to >450 m depending on winter storm intensity. The extent of mixing is directly related to interannual differences in algal growth because of the introduction of 'nutrient-rich' aphotic waters (Goldman and Jassby, 1990). The mean annual concentration of nitrate-N in the euphotic zone is only 4-5 µg/L and total hydrolyzable-P is 2-4 µg/L (Jassby et al., 1995). Secchi depths are from 15 to >25 m depending on season and year, and chlorophyll ranges from 0.25-0.75 µg/L.

Along its 192 km transit from Lake Tahoe, the Truckee River passes through the City of Reno and the surrounding arid landscape in Nevada where its receives municipal effluent and nonpoint source agricultural drainage. The Truckee River flows into Pyramid Lake, a slightly saline (ca. 5,700 mg/L TDS), desert terminal lake, and is its only major tributary. Pyramid has a surface area of 446 km2 and a volume of 26.4 km3, with a maximum depth of 103 m and a mean depth of 59 m. It lies in the high desert (1160 m elevation) and is bounded by sparsely vegetated mountains. The lake usually mixes completely during winter and is thermally stratified in the summer. It is phosphorus rich and nitrogen deficient with a dissolved inorganic N:P ratio generally <2 (Reuter et al., 1993). Pyramid is considered oligotrophic with chlorophyll typically <3 µg/L (Lebo et al., 1994a); however, massive surface blooms of the N2-fixing blue-green alga Nodularia spumigena often occur in mid-summer or early fall (Rhodes, 1995).

History of Research and Monitoring

The first scientific observations of Lake Tahoe were made as early as the 1880's by John LeConte. Intensive studies began in 1959 by Charles R. Goldman, who founded the Tahoe Research Group (TRG) with funds provided by the National Science Foundation. In 1967 the FWPCA (EPA) supplemented this work. During that period we were able to make important discoveries concerning algal growth, eutrophication, changes in water clarity, lake nitrogen and phosphorus chemistry, nutrient limitation, etc. By the late 1970's, these federally funded programs were no longer of sufficient scope to provide the extensive data base needed for land-use planning and watershed management. In 1979, the Lake Tahoe Interagency Monitoring Program (LTIMP) was established as an expansion of our Tahoe Research Group activities. LTIMP now consists of 13 federal, state and local agencies with the Directorship residing with the TRG. Lake and stream water quality monitoring, and measures of atmospheric nutrient loading fall under the realm of both LTIMP and the TRG. Sampling is done at two lake stations, multiple stations on ten tributaries, and three atmospheric deposition locations including a mid-lake station. Each year approximately 9,000 individual analyses are performed on the samples taken. Stream sampling efforts are now coordinated by the USGS. Both the TRG and LTIMP are inexorably linked to each other as well as to the University of California, Davis. Figure 2 conceptualizes this relationship and how we view the role of research and monitoring in watershed management. As a principal partner in LTIMP, the University has been able to combine its mission(s) of basic research, public service, and education to help governmental agencies achieve water quality protection.

Until 1989, water quality studies at Pyramid Lake were characterized by discrete studies and did not focus on long-term monitoring. Following the first limnological survey of the lake in 1933, work was sporadic until the 1970's when a more intensive effort by researchers at Colorado State University (e.g.

Galat et al., 1981) and the University of Nevada, Reno (e.g. Koch, 1976) defined the limnology and fish ecology of the lake. Their contribution was invaluable as it set the focus for future activities. During the period 1989-1994 we applied the model of combined research and monitoring, developed at Lake Tahoe, to Pyramid Lake. In 1989 we set up a program which monitors parameters such as temperature, light, ion concentration, nitrogen, phosphorus, chlorophyll, zooplankton, etc. Simultaneously, we worked with the tribe so that they could assume the institutional responsibility for this program once our studies were complete. This was achieved, and lake monitoring is being continued by the tribe through the Pyramid Lake Fisheries, directed by Paul Wagner. The data base is an invaluable asset for both assessing changes to the health of the lake as well as for fisheries management. This program, together with ongoing research,and an extensive state and federal monitoring effort on the Truckee River, provides a powerful tool for watershed management.

Examples of Current Research and Monitoring in Relation to Watershed Management

Lake Tahoe

Measurements of algal productivity and water clarity by the Tahoe Research Group clearly show the accelerated rate of eutrophication in Lake Tahoe since the late-1960's (ref. Figure 1). While there is interannual variation in both parameters, the long-term trend is not only statistically significant, it is now visually perceptive. Indeed, this data set is the underlying basis for nearly all major policy decisions regarding water quality in the Tahoe Basin. Examples include exportation of sewage, strict control on building, installation of major erosion control projects, establishment of water quality thresholds, and control of nonpoint source pollution. Had our program been in operation for shorter periods, albeit up to six years (i.e. 1975-1979, 1985-1990), the erroneous conclusion that clarity was improving would have been made; the result of regional droughts at these times. Together with this steady rise in algal growth and decline in transparency, was our finding of a fundamental shift from frequent N-stimulation to almost exclusive P-stimulation (Goldman et al., 1993). The response of Lake Tahoe algae to nutrient addition has been assayed using the sensitive 14C uptake method since the 1960's. Between 1967 and 1981 the frequency of algal growth stimulation by N was 43 percent. From 1982-1992 the frequency of N-stimulation dropped to only 6 percent. At the same time, 28 of 32 bioassay experiments (88 percent) since 1982 have shown significant P-stimulation. Since P is typically transported along with the suspended solids load, these findings have highlighted the importance of sediment control and erosion mitigation.

In a follow-up study we used long-term monitoring data to examine the hypothesis that atmospheric deposition of nutrients, especially nitrogen, was a significant factor contributing to the observed shift in nutrient stimulation (Jassby et al., 1994). The results suggested that a major portion of the dissolved inorganic-N (DIN), and perhaps total-N, loading to the lake comes from direct deposition of wet and dry fallout to the lake surface. Comparing deposition to loading from watershed runoff for the years 1989-1991, we found that wet + dry deposition of DIN was 19 times higher, and 4 times higher for soluble reactive-P. Given that the N:P (molar) ratio in healthy algae is about 16:1 and that the ratio was 38:1 for deposition and 9.4:1 for runoff, it was clear that atmospheric deposition of N was increasing N-

availability in the lake and causing the observed shift from N- to P-stimulation. Because much of the P-loading is still derived from the watershed, we concluded that sewage export, careful management of development, and erosion control remained the most appropriate course of action. The focus of our current research is erosion and transport of sediment and phosphorus to the lake. Examples of specific projects include; relationship between interannual variability of sediment and nutrient loading with natural and urbanized features of individual watersheds, modeling mechanisms of erosion from small scales (30 x 30 m) to entire drainage basins, evaluation of BMP effectiveness, modeling of lake response to nonpoint source loading, and paleolimnological studies of historic patterns of land disturbance and the resulting sediment transport from the watershed.

Pyramid Lake

As previously mentioned, the salinity of Pyramid Lake has increased considerably during the 20th Century due to decreasing lake volume caused by diversion of large quantities of Truckee River water for agriculture. Bioassay data show that survival of larval cui-ui entering the lake from adult spawns in the Truckee decreased dramatically between 5,839 and 8,500 mg/L TDS (Lockheed Ocean Sciences Laboratory, 1982). This prompted the US Fish and Wildlife Service (1992) to recommend in its Cui-ui Recovery Plan that TDS not exceed 5,900 mg/L. Given that current concentrations in the lake are within a few hundred mg/L of this value, and that salts accumulate in terminal lakes, there was worry that continued loading from the upstream watershed would eventually result in lake TDS exceeding the recommended concentration. In response, we developed a TDS model which predicted lake salinity as a function of lake level and Truckee River TDS load (Lebo et al., 1994b). This was then used to evaluate the trade-off, between TDS removal and the increase in lake level, to maintain a lake TDS not harmful to biota. We found that to achieve 5,900 mg/L (after 200 years) at a lake elevation of 3,794 feet (less than current lake elevation, implying increased water diversion), 100 percent of all current TDS loading to the river would need to be removed. However, if lake elevation were increased by six feet to 3,800 feet, no TDS removal would be needed to maintain the same 5,900 mg/L (after 200 years) concentration. This analysis is particularly useful to the tribe, as well as regional dischargers, water purveyors and regulatory agencies when formulating positions on flow allocation and watershed management issues.

The nitrogen (N) concentration in Pyramid Lake is an important factor affecting the amount of algal production (Reuter et al., 1993). Since one of the primary beneficial uses for Pyramid Lake is as a coldwater sport fishery upon which the tribe depends for part of its economic base, a water quality standard for nitrogen was needed which would provide both an adequate food supply to promote fish growth and at the same time insure a well-oxygenated habitat for fish survival. A consequence of eutrophication is that excessive nutrients stimulate large and frequent growths of algae which contribute to the depletion of dissolved oxygen (DO) in bottom waters as organic matter settles and is decomposed by bacteria. Using both research and monitoring data we were able to construct an empirically based model (PL-EUTR) to determine allowable N-loading to the lake (Lebo et al., 1994b). Our approach was first to quantify the relationship between within-lake and watershed N-loading, and algal growth. We then numerically linked the production of organic matter to observed changes in DO, both with depth and over an annual period. Coldwater fish generally require DO levels of at least 5-6 mg/L. Based on this, PL-EUTR predicted that to achieve a DO of 6.0 mg/L at a control depth of 70 m (and a lake elevation of

3,800 feet), dissolved inorganic-N (DIN) loading from all sources could not exceed 5,279 megagrams per year. This resulted in an average whole-lake concentration of 95 µg N/L as measured at overturn. PL-EUTR further allowed us to partition the acceptable DIN between five sources and eventually calculate total maximum daily loads (TMDL's) for the Truckee River.

Conclusion

The potential contribution of the nation's universities and other academic institutions to identification, understanding, and remediation of environmental problems is enormous. This assistance also applies to formulation of policy. We have been able to demonstrate, using examples from our limnological and watershed research at Lake Tahoe and Pyramid Lake that universities can play a major role in environmental protection efforts. Unfortunately, with current trends towards budgetary savings and agency downsizing, there is a strong danger that the priority placed on university research might be reduced in favor of within-agency alternatives. We strongly argue that this would not be in the interest of long-term environmental management and that instead, universities and governmental agencies urgently need to become stronger partners.

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Market-based Approaches and Trading-Conditions and Examples

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Management of water quality on a watershed or tributary basis provides an excellent opportunity to greatly increase application of market-based strategies including trading schemes. Discussion of market-based strategies has appeared in the Resource Economics literature during the past three decades. And administrators in the highest level of government have recently recognized the potential advantages of these strategies. For instance, in 1991 then EPA Administrator, Bill Reilly, stated "to maintain progress toward our environmental goals, we must move beyond a prescriptive approach by adding innovative policy instruments such as economic incentives." In Spring 1995, the 104th Congress said agencies must "employ market-based mechanisms that permit greatest flexibility in achieving benefits." In Spring 1995, President Clinton said, "we must rely on free markets rather than regulations to decide where and how to clean up the environment." Virginia's August 1995 Potomac Basin Tributary Strategy states, "A number of approaches...could be used...to minimize the costs of nutrient reductions. A useful example...is a system of nutrient trading." The main focus of this paper is to evaluate the potential for implementation of trading schemes, a market-based strategy, to manage water quality.

Until recently water quality was managed primarily through federal and state programs. But, in some states, significant emphasis for program responsibility has shifted to local level decision making. This emphasis provides a new and significant dimension to implementation of these market-based strategies. Program activity in Virginia's portion of the Chesapeake Bay is used as a primary example of nutrient trading and potential local level responsibility.

Approximately two-thirds of Virginia's land area drains into the Bay. Nutrient loading targets for the entire Bay and for each tributary represent a 40 percent reduction of the portion of the 1985 base load that is controllable, defined as the difference between the 1985 base load and the load from a totally forested undisturbed watershed. Original efforts to improve water quality over the past 15 years concentrated on the main stem of the Bay. But, those efforts have now moved upstream into the tributaries_all the way to the headwaters. Headwater pollutants do get to the tidal waters. As stated in Virginia's Potomac Basin Tributary Strategy, 69 percent to 91 percent of the nitrogen, and 80 percent to 91 percent of the phosphorus entering the Potomac above the fall line reaches the Lower (tidal) Potomac.

As with other areas, point sources in the Bay area have been under command and control for selected pollutants. Therefore, each point source has had a legal commitment and responsibility for control of these pollutants. As of now, discharge standards are not in place for nitrogen and phosphorus. Limited experience with sharing of responsibility and trade agreements for the controlled pollutants have existed for years among a few point sources especially in the Virginia/DC/Maryland suburbs_the Washington DC Area Council of Governments. Now, emphasis for water quality management is shifting to better management of nonpoint sources_both rural nonpoint and urban nonpoint sources. Yet, in most circumstances a legal commitment and responsibility has not been assigned or accepted for these pollutant sources.

In 1992 in the Chesapeake Bay, emphasis on nutrient control shifted from the main stem of the Bay to upland areas. Virginia's tributary strategy states, "a voluntary, area specific approach to shared nutrient reduction responsibility would allow each subarea of the basin to determine for itself how best to manage the nutrients it generates. We encourage citizens, local governments, and others to seriously consider watershed-based market incentive possibilities, which exhibit both equity and cost-effectiveness." (Actions and Options for Virginia's Potomac Basin Tributary Nutrient Reduction Strategy, October 1994, page 5-3.) This strategy, unlike the other few places which have trading schemes (Dillon Reservoir, Tar Pamlico Watershed, Lake Okeechobee, etc.), is being designed to rely heavily on local level decisions on load allocation and local decisions on implementation schemes.

The tributary strategy indicates that success in meeting nutrient levels will require added attention to point sources as well as increased effort to nonpoint sources. For point sources, technology improvements are occurring at a rapid rate in nutrient controls on treatment plants and costs are dropping. As a result of these advances nutrient controls are becoming cost-effective at increasing numbers of plants. Because most management practices to control nutrient loadings from nonpoint sources deal with run-off to streams during storm events, or with loadings to the water table, they are difficult to measure in terms of effectiveness. Of course, the effectiveness of nonpoint source nutrient reduction efforts is more difficult to define and to calculate than is the case with point sources.

Virginia's tributary strategy allows for certain types of trading for nutrient reductions. There are three primary types of trade between sources: point-point trades, point-nonpoint trades and nonpoint-nonpoint trades. Trading among sources, as well as among rivers within a state will allow states to achieve the greatest reductions at the lowest cost. For example, on a tributary where 40 percent reduction may be

extremely costly to achieve, managers may opt to make up for the shortfall by upgrading a wastewater treatment plant on another tributary to achieve the 40 percent reduction.

Virginia's tributary strategy indicates that currently available point sources and nonpoint source practices and technologies can be used to meet the overall goal. At the same time, the tributary strategy identifies some areas where the job will be more costly and difficult than other areas. This means there must be flexibility to employ the most cost-effective solutions and to deal with inequities and unfair burdens where natural or man-made conditions have created them.

In the Potomac Basin, significant nutrient-reduction measures have already been put in place for both point and nonpoint sources. But, further restrictions on discharges from selected point sources may only be met with extremely high marginal cost. It is recognized that nonpoint and other point sources might achieve the same reduction in total nutrient loadings, but at a lower overall cost to the discharger and to society. Trading schemes can be used to lower the cost of pollution control, and in addition the existence of a trading scheme also establishes incentives to prevent the creation of waste in the first place.

Necessary Conditions for Trading

This discussion will concentrate primarily on trading schemes as a way to utilize market-based strategies. The following are necessary conditions for a trading scheme to be successful:

- A binding constraint with definitive assignment of responsibility (either at the state or local level) is needed on the amount of pollution discharge and the responsibility must be enforced. Some entity must place a cap on nutrient loads and also impose some mechanism to account for future growth in loads.

- The geographic area in which trades will be effective must be specified. Trades can be allowed across the entire watershed or within small segments of a watershed. Trades will not be accepted if the trading scheme results in localized water quality problems.

- Firms must find and adopt cost-effective methods of abating their pollution so that the least cost method for the individual discharger and society can be found.

- A credit (a property right) such as an emission reduction credit or a nutrient credit must be established to allow for buying and selling of credits.

- Transaction costs, whether faced by the government or individuals, must not be too expensive.

- For trades between different sources, each source must contribute a substantial share of the nutrients.

- There must exist a sufficient number of relatively major dischargers. The potential is limited for trading if traders are too small or too few in number. If that is the case, transaction costs are too high or the opportunity to trade does not exist.

- A difference in the marginal cost of control (the additional cost of controlling an addition unit of nutrient) must exist. The system is designed to minimize cost of meeting water quality objectives. The marginal cost, additional cost per unit to control nutrients, must be different for a sufficient number of the dischargers (Table 1). In this way firms with high marginal cost of abatement can compensate those with low cost to reduce a larger quantity of nutrients. As additional treatment occurs for any individual discharger these marginal cost likely will increase for that individual. Consequently, as marginal cost converge trading opportunities disappear.

Low cost measures must be sufficiently applicable to achieve water quality objectives for any local area. The existence of cost differences is a necessary but not a sufficient condition for trading to occur. If management practices have restricted applicability in any geographic area, then the opportunity for trading is also limited. For instance, if 80 percent of farmers are now using conservation tillage then little opportunity exist to expand that practice. Likewise, forest buffers and grass buffer strips are only effective on a limited number of miles. Those constraints must be determined for each area.

Table 1. Example of cost difference in Potomac Basin.

Management Practice	Removal Cost Per Pound
Biological Nitrogen Removal	20 - 50
Urban Storm Water Retrofit	85
Urban Nutrient Management	1
Erosion and Sediment Control	254
Septic Pumpout	38
Animal Confinement Runoff	6
Livestock Waste Management	28
Ag. Nutrient Management	1
Stream Protection from Livestock	11
Grazing Land Protection	11
Conservation Tillage	19
Highly erodible Land	11
Cover Crops	3
Grass Buffers	20
Forest Harvesting	4

Decisions to be Made

Several issues must be resolved for a trading system to work:

- Terms of trade must be established. The trading ratio for a specific type of nutrient allowance trade needs to be specified. Another option is to set a fixed price per pound of nutrient reduction.

- The product must be defined. The state or local government or some other entity must create the commodity to be bought and sold in the trading scheme. In this case the commodity is a nutrient discharge

Forest Buffers	8
Shoreline Erosion Protection	54

allowance. The allowance must involve a common pollutant. The entity must be able to quantify the discharge of nutrients such as nitrogen and phosphorus. Monitoring must be available. Some form of enforcement and compliance must exist. Without a binding and enforceable nutrient limit or cap on a source's allowable nutrient load, a source has no incentive to seek out and trade with sources with lower cost.

- A demand for pollution allowance must be created. In order to create a tradeable product, nutrient allowances must be measured, quantified, and assigned to individual sources. A discharge limit must exist. Without some enforceable limit, there is no financial incentive to trade or to invest in innovative and cost saving nutrient reduction measures.

- The trading environment must be defined. In order for a trading system to operate effectively, the legal and financial rights and responsibilities of sources involved in a nutrient trade must be clearly specified and certain. In this case, strict discharge limits for the pollution in question, such as nitrogen or phosphorus, must be established within the trading area. Some entity with power to act must accept or assign responsibility for limiting nutrient loads for individual sources. Ultimate responsibility for nutrient reduction must be clearly articulated and certainty of conditions must be known about future rule changes.

A successful trading operation is complex and will require funding. Administrative activities such as quantifying nutrient allowances, monitoring, and enforcement of trade agreements require staff time and management effort. Some entity must provide these administrative functions for a trading system to be successful.

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Market Incentives: Effluent Trading in Watersheds

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For over 15 years, the U.S. Environmental Protection Agency (EPA) has studied the feasibility and applicability of different types of effluent trading to cost-effectively achieve water quality objectives including water quality standards. By trading, a pollution source that can more cost-effectively achieve greater pollutant reduction than is otherwise required can sell or barter the credits from its excess

reduction to another source unable to reduce its pollutant load as cheaply. To ensure that water quality objectives and standards are met throughout a watershed, an equivalent or better water pollutant reduction would need to result from a trade.

Attention to effluent trading was elevated on March 16, 1995 when President Clinton and Vice President Gore released Reinventing Environmental Regulation, a "strategy to reinvent environmental protection ... to produce a new era of cleaner, cheaper, and smarter environmental management." Twenty-five high priority actions were presented, one of which was to promote effluent trading in watersheds as a lower cost tool to achieve water quality objectives and standards. EPA was committed to establish a framework for different types of effluent trading, issue policy guidance for permit writers, and provide technical assistance to those interested in developing trading programs.

EPA formed an intra-agency work group in July, 1995 to fulfill these commitments. On January 25, 1996, the Agency released a Policy Statement which communicates EPA's current policy on effluent trading. In addition, EPA released for public comment a draft framework for trading in early Spring 1996. EPA is also planning to hold at least two public meetings during mid-1996 to obtain feedback on the draft trading framework, provide a forum for exchanging information, identify opportunities for new trading programs, and work to overcome barriers to developing and implementing trading programs.

Types of Trading

EPA has identified several forms of effluent trading and described them in detail in the Policy Statement and draft framework. These include the types of trading that are currently better understood and accepted. However, the two documents acknowledge that other forms of trading are or may also be possible.1 The forms of trading discussed in these documents were:

- Intra-Plant: A point source is allocated pollutant discharges among its outfalls in a cost-effective manner, provided that the combined permitted discharge with trading is no greater than the combined permitted discharge without trading in the watershed.
- Pretreatment: An indirect industrial point source(s) that discharges to a publicly owned treatment works arranges, through the local control authority, for additional control by other indirect point sources beyond the minimum requirements in lieu of upgrading its own treatment for an equivalent level of reduction.
- Point/Point: A point source(s) arranges for other point source(s) in a watershed to undertake greater than required control in lieu of upgrading its own treatment beyond the minimum technology-based treatment requirements in order to more cost-effectively achieve water quality standards.
- Point/Nonpoint: A point source(s) arranges for control of nonpoint source discharge(s) in a watershed in lieu of upgrading its own treatment beyond the minimum technology-based treatment requirements in order to more cost-effectively achieve water quality standards.
- Nonpoint/Nonpoint: A nonpoint source(s) arranges for more cost-effective control of other nonpoint sources in a watershed in lieu of installing or upgrading its own control.

Reasons to Trade

Trading is an innovative way for community stakeholders (e.g., regulated sources, non-regulated sources, regulatory agencies, and the public) to develop more cost-effective solutions to address the water quality problems in their watersheds or sewer districts. Trading does not replace the current regulatory approach; instead, trading supplements it. Trading offers a number of potential economic, environmental, and social benefits:

- Potential Economic Benefits:
  - Reduces overall costs for sources contributing to water quality problems.
  - Allows dischargers to take advantage of economies of scale and treatment efficiencies that vary from source to source.
  - Reduces overall cost of addressing water quality problems in a watershed.
  - Provides a way to manage growth and still achieve environmental objectives.
- Potential Environmental Benefits:
  - Achieves equal or greater reduction of pollution (and therefore greater than or equal environmental improvement) for the same or less cost.
  - Creates an economic incentive for dischargers to go beyond minimum pollution reduction and also encourages pollution prevention or the use of other innovative technologies.
  - Reduces cumulative pollutant loading, improves water quality, accommodates growth, and avoids environmental degradation.
  - Addresses the broader environmental goals within a trading area, e.g., ecosystem protection, ecological restoration, improved wildlife habitat, and endangered species protection.
- Potential Social Benefits:
  - Encourages dialogue among stakeholders and fosters concerted and holistic solutions for watersheds with multiple sources of water quality impairment.

Threshold Conditions for Trading

Experience to date has shown that there are numerous threshold criteria that need to be met in order for trading to be feasible. These are summarized below:

- Trading programs are consistent with current regulations and enforcement mechanisms.
- At a minimum, applicable technology-based requirements are complied with.
- Where applicable, water quality standards are met and/or maintained.
- Pollutants included in trades are dependent on water quality problem.
- Boundaries and markets for trading are well defined and no larger than a watershed.
- Cost differences in pollutant load reductions exist across sources.
- Transactions costs are minimized.
- Terms of trades are defined and agreed upon, including trading ratios and local impacts.

- Trading program is developed within an appropriate analytical and planning framework.
- There is access to adequate data on baseline, desired, proposed, and trading-induced pollutant load and water quality levels.
- Monitoring to measure pollutant loads or water quality levels as appropriate.
- Development of trading program involves stakeholders and public participation.
- Accountability for all trading parties is established along with tracking mechanism for trades.
- Adequate measures are provided to safeguard achieving or maintaining water quality objectives and re-examine trading programs and trades after they expire.

Experience to Date

Trading is being explored, developed, or implemented in a number of watersheds throughout the United States. Some examples are listed in Table 1. Substantial cost savings have been estimated for some of the trading programs in place. For example, at least 10 iron and steel facilities have used intra-plant trades, with seven of these providing cost savings estimates. During the period 1983-1993, these facilities saved an accumulated $123 million (1993$). A key component of these trades is that trades must result in net reductions in the total quantity of total suspended solids and oil and grease discharged (approximately 15 percent) and all other pollutants, including heavy metals (approximately 10 percent).

Table 1. Trading programs implemented or under development or consideration.

Project/Location	**Focus**	**Type of Trading**
Trading Programs Implemented:		
Arkansas Nature Conservancy	wetlands	nonpoint/NPS
Boulder Creek, Colorado	ammonia	point/stream improvement and riparian restoration
Chatfield Basin, Colorado	phosphorus	point/NPS
Cherry Creek, Colorado	phosphorus	point/NPS; point/point
Dillon Reservoir, Colorado	phosphorus	nonpoint/NPS
Iron and steel industry	total suspended solids, oil and grease, lead, zinc	intra-plant
Maryland Nontidal Wetlands	pathogens, phosphorus	nonpoint/NPS

New York City, New York	pathogens, phosphorus	drinking water/NPS and point; point/NPS; point/point
Tar-Pamlico, North Carolina	nitrogen, phosphorus	point/NPS; point/point
Trading Programs Under Development or Considerations		
Chehalis River Basin, Washington	biological oxygen demand and fecal coliform	point/NPS
Long Island Sound, New York	nitrogen	point/point; point/NPS
Providence, Rhode Island	metals	pretreatment
South San Francisco Bay, California	copper	point/point
Stamford, Connecticut	nitrogen	point/point; point/NPS
Tampa Bay, Florida	nitrogen, total suspended solids	point/point; point/NPS; nonpoint/NPS
Truckee River, Nevada	nutrients, dissolved solids	point/NPS; water quantity

Boulder Creek, Colorado chose to improve stream flow, restore the riparian zone, and install some nonpoint source control measures rather than upgrade its municipal treatment facility to remove more ammonia. They have saved up to $3.4-$3.5 million (1994$/1995$) in capital costs and gained greater improvements to the environment, such as through improved streambank stabilization, reduced streambank erosion and improved filtration of runoff, improved fish habitat, more continuous protected riparian zone for wildlife, and increased wetland area. In Tar-Pamlico, North Carolina, up to $20-$45 million (1994$/1995$) in capital cost savings in first phase of their nutrient reduction strategy has occurred through use of point source trading. Cost savings of 65-80 percent are expected through use of point/NPS trading during the second phase.

How EPA Will Encourage Trading

Rather than develop a detailed guidance, EPA has developed a draft framework for effluent trading. It has also planned workshops to exchange information. Limited technical assistance for trading projects in specific areas is also being contemplated. EPA will continue to encourage effluent trading on a voluntary basis under existing Clean Water Act authorities. There has been a substantial public outreach effort to obtain stakeholders' recommendations and insights on the draft framework.

Finally, while EPA believes that the potential of trading is largely untapped, the usefulness of trading will depend on the site-specific water quality problems in any given situation. The framework describes

situations which EPA believes are more widely accepted for effluent trading and those that are generally inappropriate.

Conclusion

Given the mounting pressure to balance environmental improvement with economic constraints, market-based economic incentives such as effluent trading, are gaining interest and support. As more trading programs are developed, implemented, and evaluated, their successes should not only give birth to similar programs elsewhere but also to additional ways to use the trading concept.

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The Tar-Pamlico Experience: Innovative Approaches to Water Quality Management

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Statement of the Problem: How to Address Nutrient Pollution From Nonpoint Sources?

I. Introduction

The United States Environmental Protection Agency (EPA) estimates that runoff from agricultural operations is the principal source of pollution in our nation's waters, affecting 57 percent of lake acres and 60 percent of river and stream miles in states reporting water quality impairment. Nutrients (usually nitrogen and phosphorus) are the largest group of pollutants from these nonpoint sources and are among the most common causes of degradation to lakes and estuaries.

The federal Clean Water Act, passed in 1972, addresses surface water pollution control by focusing on point sources of water pollution, such as municipal sewage treatment plants or industries. Under the Act, EPA or delegated states issue permits to point sources to limit the level of pollutants these facilities can

discharge. Significant gains in water quality have resulted from this point source permitting system, but as a result the relative significance of nonpoint source pollution to water quality impairment has increased.

Currently the Clean Water Act contains no permit requirement or other mandatory limitations on nonpoint sources of pollution. In most areas, control of nonpoint sources depends on the voluntary implementation of best management practices (BMPs). Funding of voluntary BMPs, usually through state agricultural cost-share programs, is often inadequate to control nonpoint source pollution, and enforcement and maintenance of voluntary BMPs is sporadic.

Nonpoint source pollution is difficult to regulate because it involves large areas of land and generally only occurs with precipitation events, which are impossible to predict accurately. In addition, unlike point source control, nonpoint source pollution control requires the regulation of local land use, which is traditionally within the jurisdiction of local governments rather than the federal government.

To reduce nutrient pollution from nonpoint sources in the Tar-Pamlico River Basin of North Carolina, a nutrient reduction trading system has been established between point and nonpoint sources of pollution in that watershed. Pollutant trading programs can take many forms, but, in the Tar-Pamlico, the concept was to allow regulated point sources to meet water quality-based effluent limits by the most cost-effective means, including paying for reductions in nonpoint source pollution within their watershed. By giving point sources credit for specified nonpoint source controls, the trading program creates an economic incentive for point sources to help reduce nonpoint source discharges.

II. History of the Project

The Tar-Pamlico River Basin is an approximately 5,400 square-mile watershed of the Tar and Pamlico Rivers and their tributaries. Over the past three decades, the Tar-Pamlico estuary has experienced increased algal levels due to excess nutrients entering the estuary from the Tar-Pamlico River. Such increased algal levels have led to fish kills, diseases in aquatic life, odors, wildlife habitat loss

and generally diminished water quality.

In the Pamlico Estuary, nitrogen is generally considered to be the nutrient limiting phytoplankton growth. According to the most recent water quality studies in the watershed, approximately 90 percent of the nitrogen entering the Tar-Pamlico River is from nonpoint sources. Most of this nonpoint source nitrogen pollution is from agricultural sources.

In addition to agricultural operations, sources of nutrient pollution in the basin include urban run-off, septic tanks, marine vehicles, and discharges from municipal and industrial wastewater treatment plants. Municipal wastewater discharges to the basin average about 33 MGD or approximately 10 percent of the overall nitrogen load to the estuary. The largest point source in the basin is Texas Gulf's industrial discharge of phosphorus from its mining operations.

III. Traditional Responses to Nutrient Pollution Concerns

In 1989, pursuant to a petition from the Pamlico-Tar River Foundation, the Environmental Management Commission designated the Tar-Pamlico watershed as "Nutrient Sensitive Waters" (NSW) and, in April 1989, the Division of Environmental Management (DEM) issued a nutrient management strategy. The management plan's goal was to have no long-term increase in nitrogen and phosphorus inputs from point sources and a decrease in inputs from nonpoint sources. The state prepared a nutrient budget for the watershed based on a 1988 study that indicated 85 percent of the nitrogen load came from nonpoint sources of pollution, primarily agricultural sources, and only 15 percent came from point sources.

The proposed management plan called for point source effluent limitations on new and expanding facilities of 2 mg/l year-round for total phosphorus and 4 mg/l in the summer and 8 mg/l in the winter for total nitrogen. This plan ensured that as facilities grew to meet their design flows (28 MGD existing/45 MGD design), improved treatment would offset the effect of flow increases. In all, a 30 percent decrease in existing point source loadings would occur or a basinwide nitrogen

load reduction of 4 percent.

In the 1989 nutrient management report, DEM acknowledged the high cost of meeting the proposed nutrient limitations and major concerns regarding the cost-effectiveness of point source nutrient removal. To meet the proposed point source limitations, dischargers would have to build advanced treatment facilities to control their nutrient loading. Capital costs for implementing the nutrient control measures were estimated by the dischargers to be at least $50 million. Further O&M costs were also projected. These high treatment costs were especially troublesome given the relatively small effect of point source nitrogen removal on the overall nutrient budget for the watershed.

IV. Development of An Alternative Watershed Planning Approach

In 1989, a group of twelve municipalities and one industry located in the Tar-Pamlico watershed joined together to form the Tar-Pamlico Basin Association, Inc. (the "Association"). The purpose of the Association was to present an alternative strategy to the state based on a more holistic approach to water quality management that addressed both point and nonpoint sources of pollution in the entire Tar-Pamlico watershed on a cost-effectiveness basis. The alternative strategy was intended to foster immediate point source reductions while establishing a management framework for addressing nonpoint sources over a multi-year period. Pollution prevention and a research program to address technical uncertainties were the critical aspects of the alternative approach.

The two-phased alternative strategy developed by the Association, the Environmental Defense Fund (EDF), the Pamlico-Tar River Foundation, and the North Carolina Division of Environmental Management contained the following elements:

1. immediate nutrient load reductions through optimization of treatment plant performance;
2. development of a hydrodynamic estuary model to evaluate nutrient impacts, alternative pollution control strategies, and set nutrient loading targets;

3. establishment of a schedule of short term nutrient reduction goals to ensure that point source loads decrease;
4. development of the management framework to target and track nonpoint sources; and
5. initiation of a best management practices (BMPs) pilot program to demonstrate the efficacy of point/NPS source trading.

In December 1989, after considerable discussion and debate, the North Carolina Environmental Management Commission approved the alternative strategy, and an agreement was signed by the Tar-Pamlico Basin Association, the State of North Carolina's Division of Environmental Management, the Environmental Defense Fund, and the Pamlico-Tar River Foundation.

V. Issues to Consider in Developing a Point/Nonpoint Source Trading Program

How effective a trading program will be in reducing the costs of achieving environmental objectives will, in many instances, be directed by:

- the relative contribution of pollution from various sources;
- the marginal cost of increased point source treatment; and
- the certainty to which various pollution sources may be abated.

In the Tar-Pamlico case, data were not available for all of these critical factors. Therefore, a phased approach to implementing the trading program was established. During Phase I of the Tar-Pamlico agreement (1990-1994), the focus of the project was to develop information regarding nutrient loading to the estuary, augment the state's agricultural nonpoint source control program, and create an infrastructure for more refined nutrient management in the watershed. During Phase II (1995-2004), the long-term nutrient reduction strategy will be implemented based on the information and management tools developed in Phase I.

VI. Management Tools Necessary for a Nutrient Trading Program

To effectively implement a nutrient trading program, management tools must be developed to accurately track and target point and nonpoint source nutrient discharges:

- Models should be developed to assess the relative loadings from various pollution sources and, if possible, the fate and transport of pollutants so that objective pollution reduction targets may be set;
- Management systems should be developed to identify nonpoint sources and select priorities for nonpoint source controls such as a GIS system;
- Demonstration projects should be developed where nutrient reductions from nonpoint sources are unclear; and
- Personnel must be available to implement these programs and coordinate among various regulatory programs.

The Tar-Pamlico agreement required development of these fundamental tools as part of the trading program. In order to target nonpoint sources of nutrient pollution, a water quality model of the estuary and a Geographic Information System (GIS) of the watershed were developed. These models, once completed, will allow the state to identify nonpoint sources of pollution, target implementation of nonpoint source controls, and better determine load relationships between point and nonpoint sources in the river basin.

VII. Elements of a Trading Program

There are a number of basic elements that need to be present to establish an effluent trading program, or probably any other innovative watershed management program. These elements include:

- analyses demonstrating the benefits of the innovative approach;
- development of a group agreement;
- funding commitments for the alternative strategy;
- regulatory acceptance;
- achievement of implementation schedules and enforcement of program terms;

- regulatory coordination and assistance; and
- development of a reporting and monitoring program.

Each of these elements is necessary for formation, acceptance and implementation of a trading program.

VIII. Conclusion

The concepts of point/NPS source trading and watershed-based management have become increasingly popular since the Tar-Pamlico project began. Despite some initial skepticism, EPA is now pointing to the Tar-Pamlico project as a model for cost-effective and innovative water quality control. Both House and Senate versions of the Clean Water Act reauthorization bills for the last two years have contained provisions for a watershed approach to water quality improvement. All signs indicate, that watershed-based water quality control and cost-effective alternatives such as point/NPS source trading are the wave of the future.

As nutrient trading becomes more widely implemented and its framework is further refined, several key issues will need to be addressed through research and policy decisions. Among these are whether the life of a BMP credit should be limited and whether the value of a BMP credit should be discounted over its life; whether all point source dischargers should continue to receive the same credit for nutrient removal regardless of their location within the watershed; and how spatial, temporal, or seasonal variations in nutrient impacts can best be addressed through watershed management. Answers to these questions have not yet been resolved through the Tar-Pamlico trading program experience. These and many other issues are sources of future research and investigation in this growing area of water quality control.

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Cost-Effectiveness and Targeting of Agricultural BMPs for the Tar-Pamlico Nutrient Trading Program

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The Tar-Pamlico Nutrient Trading Program is a pioneering effort to more effectively manage nutrient inputs to an estuary. Much has been written about the institutional arrangements behind the Program. This paper discusses some of the technical work that supports Program implementation. In order to help the Program participants set a reasonable cost for trading nitrogen or phosphorus between point and nonpoint sources and understand how cost effective different best management practices (BMPs) are, we developed cost-effectiveness estimates (expressed as $/kilogram of nutrient load reduced) for cost-shared agricultural BMPs in the Basin. Most prior work of this type has generated a single cost-effectiveness value for each BMP. An interesting aspect of these estimates for the Tar-Pamlico is that cost effectiveness values are based on conditions prior to installation of a given BMP. Incorporating pre-existing

conditions into the calculations accounts for the reality that the same BMP can have widely varying cost effectiveness when applied to different sites, which has implications for targeting cost-share dollars to farmers.

Sources of BMP Cost and Effectiveness Data

BMP unit costs were calculated for the major cost-shared practices in the Tar-Pamlico basin. These values were based on NC Division of Soil and Water Conservation records and were adjusted to include farmer contributions, operation and maintenance costs, area benefitted, and BMP life expectancy. The data represent BMPs that were implemented from 1985 to 1994. Costs for this study were not corrected for inflation. The cost values given in the North Carolina Agricultural Cost-Share summaries include only funds expended by state and federal cost-share programs. Cost-share funds are generally limited to 75 percent of the total cost of the practice, with the remaining funds being contributed by the farmer. For the purposes of our calculations, we assume that the reported cost-share figures represent 75 percent of the total cost of the practice.

A literature review was conducted to determine the most relevant studies on which to base estimates of BMP effectiveness in the basin. Effectiveness data specific to the Tar-Pamlico basin were available for animal waste management practices and for water control structures. The effectiveness of conservation tillage practices was estimated based on results of the Chesapeake Bay Watershed model for the Southeastern Plains and Middle Atlantic Coastal Plains ecoregions. The effectiveness of terracing practices was estimated based on the combined results of two empirical studies in the Chesapeake basin. Vegetated filter strip effectiveness was determined based on two other Chesapeake basin studies that used filter strips of similar size to those cost-shared in the Tar-Pamlico basin. For the remaining practices, only cost data are presented because effectiveness data were not available.

For several practices, cost-effectiveness values show considerable ranges that represent the variability in pre-BMP nutrient loading across different sites. The ranges do not capture other sources of variability such as the site-specific

variations in BMP cost or effectiveness. The cost data from this study represent the direct cost of implementing BMPs. Other "less direct" costs such as (1) opportunity costs from loss of productive land to BMPs and (2) costs of not implementing BMPs (e.g., higher fertilizer costs, offsite costs resulting from pollution impacts) are not addressed.

It is important to note that BMP effectiveness values for different practices are not necessarily additive. For example, a practice installed on conventional tillage may result in a 10 percent net nutrient load decrease. However, the same practice installed on conservation tillage will not necessarily yield 10 percent further reduction in the runoff nutrient load.

Results

Table 1. Some nutrient reduction cost-effectiveness estimates for cost-shared practices in the Tar-Pamlico Basin

				Cost-Effectiveness in Reducing Nutrient Loads to Surface Runoff and Subsurface Drainage (Relative to Preexisting Practice) ($/kg of nutrient reduced)	
Cost-shared practice	**Pre-existing practice**	**Portion of Basin**	**Nutrient**	**Using 20-year lagoon life**	**Using 10-year lagoon life**
Anerobic lagoons	Undersized lagoon with land application at 2x agronomic rate	Whole basin	Nitrogen	$5 to $21	$6 to $29
			Phosphorus	$19 to $298	$26 to $395
	Undersized lagoon with land application at 3x agronomic rate	Whole basin	Nitrogen	$2 to $11	$3 to $14
			Phosphorus	$10 to $158	$13 to $209
	Undersized lagoon with land application at 4x agronomic rate	Whole basin	Nitrogen	$2 to $7	$2 to $9
			Phosphorus	$6 to $108	$9 to $142
	Direct discharge of	Whole basin	Nitrogen	$0.02 to $4.14	$0.02 to $5.48

	animal wastes		Phosphorus	$0.03 to $4.00	$0.02 to $5.30
Land application	Land application at 2x agronomic rate	Whole Basin	Nitrogen	$0.59 to $4.81	
			Phosphorous	$2.41 to $75.65	
	Land application at 3x agronomic rate	Whole Basin	Nitrogen	$0.30 to $2.30	
			Phosphorous	$1.20 to $37.86	
	Land application at 4x agronomic rate	Whole Basin	Nitrogen	$0.20 to $1.56	
			Phosphorous	$0.80 to $25.24	
	Direct discharge of lagoon effluent and sludge	Whole Basin	Nitrogen	$0.04 to $0.22	
			Phosphorous	$0.05 to $0.25	
	Direct discharge of animal wastes	Whole Basin	Nitrogen	$0.01 to $0.06	
			Phosphorous	$0.01 to $0.09	

Table 1 summarizes the cost-effectiveness estimates for only a few of the practices for which both cost and effectiveness data were available. Space limitations prohibit presenting complete results in this paper. These estimates represent the direct cost of implementing BMPs. Other "less direct" costs such as (1) opportunity costs from loss of productive land to BMPs and (2) costs of not implementing BMPs (e.g., higher fertilizer costs, offsite costs resulting from pollution impacts) are not addressed. Specific findings include:

- The cost-effectiveness of animal waste management practices is highly dependent upon the preexisting waste management practice on a farm. The range of the cost-effectiveness estimates for any given scenario can be quite broad due to variability in (1) nutrient content of the waste and (2) the crop's fertilization requirement.
- Water control structures are highly cost-effective for nitrogen control but not for phosphorus control.
- Nutrient management is not cost-shared in the basin, yet it has been shown to be highly cost-effective.
- Relative to other cropland BMPs, conservation tillage can be a cost-effective practice for both nitrogen and phosphorus reduction, especially when used in conjunction with nutrient management.

- Relative to other practices, terracing is not cost-effective for either nitrogen or phosphorus reduction.
- Cropland conversion could potentially be very cost-effective, but this depends greatly on site-specific factors.
- Insufficient data exist to estimate the effectiveness (and therefore, cost-effectiveness) of grassed waterways, diversions, and stripcropping.
- Although data are presented by BMP type, it is important to realize that holistic farm management is more cost-effective than single-objective BMP cost-sharing.

Based on our findings and literature review, we offer the following suggestions for programmatic direction:

- The Agricultural Cost Share Program could place a higher priority on nutrient (and particularly, nitrogen) management. Nutrient management has been proven to be a cost-effective strategy for reducing both edge-of-field and watershed loading from agricultural lands.
- Increasing the cost-effectiveness of cost-sharing will require an increased commitment to education and technical assistance.
- The Nutrient Trading Program is in a position to take a proactive approach to restoring and protecting land uses and land cover types that provide positive water quality benefits. The cost-effectiveness of this approach needs to be determined.

Phase II Trading Value

One outcome of this study was use of the results to develop an improved cost value for point source-nonpoint source trading. Based on the cost-effectiveness ranges presented in this report, the N.C. Division of Environmental Management (NCDEM) selected the following scenario as the basis for estimating a trading value for Phase II of the Nutrient Trading Program:

Practice:	anaerobic lagoons

Preexisting practice:	undersized lagoon with land application at 2 times the agronomic rate
Lagoon life span:	20 years
Nutrient:	nitrogen

Our estimated cost-effectiveness range for the above scenario is from $5 to $21 per kilogram of nitrogen reduced (Table 1). To estimate a single trading value, NCDEM multiplied the median of this range ($13/kg nitrogen) by a safety factor of 2 and then added a 10 percent administrative cost. The resulting figure was $28.60, which was rounded to $29/kg nitrogen.

The full study results are contained in Cost Effectiveness of Agricultural BMPs in the Tar-Pamlico River Basin (Tippett and Dodd, 1995) prepared by RTI for NCDEM.

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Nonstructural Management Practices for Watershed Protection

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Introduction

This paper contains a brief summary of nonstructural controls being implemented by state and local governments to protect surface waters, sensitive areas, and groundwater from the harmful effects of development. The nonstructural controls identified are those the authors consider noteworthy based on examples found in the literature and experience from reviews of state coastal nonpoint source control programs submitted to EPA and NOAA to meet requirements of Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). Because EPA and NOAA are in the initial stages of this review, most of the examples cited here were identified through literature reviews.

The Problem

When previously undeveloped land in a watershed is disturbed for any reason, impacts to surface waters are almost always unavoidable. These impacts can occur due to sediment from eroded exposed soils and increases in runoff volumes and peak flows which cause changes to hydrology in downstream channels, wetlands, and riparian areas.

The increased sediment from areas disturbed during construction can clog small tributaries, alter habitat, smother fish eggs and fill in wetlands that previously provided detention and retention of rainfall runoff. After construction, erosion of poorly stabilized land can continue to cause similar problems.

Increases in impervious surfaces such as roads, rooftops, and parking lots can increase the total amount of runoff and peak flows that negatively impact local drainage systems. For example, the total runoff volume from a one-acre parking lot is about 16 times that produced by an undeveloped meadow (Techniques, 1994). Impacts from increasing imperviousness include lower base flows and channel widening. Flooding may also result, especially in communities within the flood plain.

Daily activities also generate nonpoint source pollution. Oils, gas, engine coolants, and metals from vehicles wash off roads and parking lots. Improperly applied fertilizers and pesticides from lawns and parks/golf courses, pet wastes, and improperly disposed household wastes (such as engine oils and coolants, paints, pesticides, and solvents) can also contribute to nonpoint source loadings.

The Challenge

The challenge for state and local governments to prevent and reduce nonpoint source related impacts due to development in a watershed is daunting. Fortunately, many state, county, and municipal governments have established regulations, policies, and procedures to implement management practices to minimize the short and long-term effects of development on surface waters and ground waters. These management practices, often referred to as Best Management Practices or BMP's, can be structural or nonstructural. Structural management practices involve construction of an engineered facility to control runoff flow and pollutants, such as sediment basins, detention ponds, and manmade wetlands. Nonstructural management practices, which are the subject of this paper, are programmatic tools to prevent and mitigate NPS pollution. They include policies, legislation, and procedures to: manage land use and protect important natural areas such as wetlands; educate the public and practitioner, e.g., contractor certification programs; and control the sources of NPS pollution, e.g., oil recycling programs. The emphasis of this paper will be on those nonstructural controls that maintain the pre-development characteristics of the watershed by preserving the natural hydrology and buffering capacity of land. Surface and groundwater quality protection, flood control, erosion control and toxic substance reduction are among the goals of nonstructural programs.

In most cases a combination of nonstructural and structural practices is necessary to implement a well balanced nonpoint source control program. For example, empirical data from Hybernia, a 132 acre residential development in Illinois, suggest that use of upland vegetated systems (nonstructural open space) in combination with ponded areas (structural) has resulted in the rate and volume of discharge to be essentially unchanged before and after development (EPA, 1995).

Nonstructural Management Practices

Conservation and Open/Green Space

In the Washington, D.C. metropolitan area, standardized tree protection measures to protect critical forest

stands necessary to maintain water quality and biological integrity have been adopted. These measures include: forest surveys, identification of high priority forests to protect during planning, development and construction and long term provisions to ensure protection of the forests. (Metropolitan Washington Council of Governments Restoration Sourcebook).

Major cities such as Baltimore, Maryland, Portland, Oregon, and Seattle, Washington are developing green space programs to protect and connect natural areas while proving recreational activities. Funds to assist in this effort are available from FHWA under the Intermodal Surface Transportation Efficiency Act of 1991 (Land and People, 1993). New York City is proposing to establish regulations to establish both land use plans and watershed protection controls to protect and maintain water quality in its Catskill and Delaware drinking water supplies. The cost of source control including the purchase of land is estimated to be much less that the cost of adding filtration systems.

In Washington State, the Evergreen Agenda Project is building a fund for local communities to use to purchase open land, thereby protecting land they believe should be conserved from development (Land and People, 1994).

Cluster development is known to provide more open space, recreational areas, less impervious area, and many other benefits when compared to traditional developments (Techniques, 1994).

Protection and Preservation

Florida's Everglades Protection Act defines an everglades protection area and mandates storm water treatment areas in drainage to the everglades in which BMP's are to be constructed to reduce phosphorus.

Olympia, Washington requires downstream evaluation as a part of its storm water management program to assure protection of downstream channel stability from maximum velocities. New Jersey and Washington State storm water management programs contains similar requirements at the state level (WMI, 1996).

The Southwest Florida Management District developed model ordinances for local governments as part of Florida's Surface Water Improvement and Management (SWIM) program. These models include protection of environmentally sensitive habitats, protection and establishment of vegetative buffer zones, and protection of stream banks and shorelines (EPA, 1995).

An eight-mile greenbelt was purchased to protect Barton Springs in Austin, Texas from pollution, but increasing development still threatens the uses of this resource. Austinites have approved an ordinance which sets stringent levels on new development. One requirement is that no more than 15% of any tract can be covered with impervious surfaces (Frech, 1994). Recently, judiciary and legislative processes may reduce the effectiveness of this ordinance, but the Austin community is continuing to resist urban sprawl that threatens Barton Springs (Nonpoint Source News-Notes, 1995).

Buffer Establishment and Protection

The City of Lacey, Washington, using the Washington State Department of Ecology's model wetland protection ordinance as a base, implemented an ordinance to protect wetlands and stream corridors. A key feature requires buffers with sizes that vary depending on the value of the wetland and intensity of the land use (Schueler, 1994). Baltimore County (MD) Code requires setbacks of buildings from buffers, management to protect and preserve buffers, and buffers around stream corridors, with special requirements to protect steep slopes and erodible soils (Schueler, 1994).

The New Jersey Pinelands Commission comprehensive management program for wetlands not only prohibits development within wetlands but also requires an upland buffer of 300 feet in which no development can occur (Terrene Institute, 1995).

The Massachusetts Wetland and Floodplain Protection Act requires permits for any work within a buffer zone of 100 feet from wetlands and the 100 year flood level (Terrene Institute, 1995).

A detailed discussion of stream buffers can be found in Techniques, (Summer 1995), which the authors recommend as an excellent resource.

Construction and Runoff

Olympia, Washington's storm water management program is integrated with local land use planning, zoning, wetlands protection, floodplain protection, land acquisition, wellhead protection, and building approval programs. Other agencies with similar integrated programs include Maricopa County, Arizona, Snohomish County, Washington, and Somerset County, New Jersey (Watershed Management Institute, 1996).

For Chesapeake Bay Program Tidewater Areas, Virginia's storm water control programs establish more stringent requirements for impervious areas, storm water controls and erosion and sediment controls.

Grand Traverse County, Michigan has enacted a soil erosion and storm water control ordinance which contains many nonstructural as well as structural requirements. General standards include designs and measures to provide for non-erosive velocities of runoff, preventing alterations to drainage which may create downstream flooding or sedimentation, and consideration of affected wetlands and other sensitive areas (Grand Traverse County, 1992).

Delaware requires training and state certification for inspectors and contractors. Certified Construction Reviewers ensure the adequacy of construction pursuant to the approved sediment and storm water management plan (Watershed Management Institute, 1994). Florida is implementing a similar program (Watershed Management Institute, 1996).

Community Based

Other nonstructural controls that have been established by many states, counties, regional areas, and cities include storm drain stenciling, street sweeping (especially on bridges), certification of pesticide and herbicide applicators for maintenance of public green space and roadsides, establishing public education/outreach programs for fertilizer and pesticide use and disposal of household wastes, and recycling programs for oil and anti-freeze (Watershed Management Institute, 1996).

Summary

Nonstructural practices are being promoted, required and used by all levels of government to reduce the potential impacts of new development. Nonstructural practices are essential elements in all comprehensive watershed protection programs. And as an added benefit, where structural controls are required, nonstructural controls can help significantly reduce the costs of providing and maintaining structural controls, enhance both the performance and longevity of these complex engineered practices, and, even replace them in certain instances (Horner et. al., 1994).

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A Watershed Approach to Flood Hazard Mitigation and Resource Protection: The President's Floodplain Management Action Plan

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Figure 1. A naturally functioning riverine system, the Yellowstone River, Yellowstone National Park.

Introduction

The floodplains of the United States contain a wealth of natural and cultural resources that are of immense value to the Nation. However, most floodplains have been adversely impacted by human activities to the extent that their resources have been significantly degraded or destroyed. Despite expenditures of billions of Federal dollars trying to keep floodwaters away from people, mostly with structural measures such as dams and levees, flooding remains the greatest threat and most persistent natural hazard facing over 20,000 communities in the United States. This century alone floods have caused a greater loss of life and property, and disrupted more families and communities than all other natural hazards combined. Until recently, it was the policy of the Federal government to encourage and fund major flood-control projects and so, in no small way, contributed to the loss and degradation of our floodplain resources. It has only been in recent years that floodplain lands and waters have come to be recognized and appreciated as being some of the most ecologically productive, hydrologically important, and environmentally sensitive areas within a watershed. It is therefore imperative that we protect and restore these critical areas to ensure the integrity of natural systems, as well as the sustainability of our communities.

Floodplain Management: A New Vision

A new way of thinking about reducing flood losses first emerged in 1942 when a graduate student by the name of Gilbert White completed his doctoral dissertation, Human Adjustment to Floods: A Geographic Approach to the Flood Problem in the United States, wherein he noted that "floods are an act of God, flood damages result from the acts of men." He went on to advocate "adjusting human occupancy of the floodplain environment so as to utilize most effectively the natural resources of the floodplain, and at the same time, of applying feasible and practicable measures for minimizing the detrimental impacts of floods." In the decades following Dr. White's new paradigm for floodplain management, some efforts were made to implement other measures, besides structural flood control, to reduce flood losses without destroying the natural resources and functions of floodplains. These efforts, however, were mostly limited in scope and the focus continued to be large structural projects funded by the Congress. It is of interest to note that, while working in the Executive Office of the President, Bureau of the Budget, Gilbert White advised President Roosevelt to veto the 1936 Flood Control Act which provided full federal funding for large civil works projects such as dams and levees.

During the 1960's the Congress recognized that flood losses and disaster relief expenditures were continuing to escalate and in 1965 established a Task Force on Federal Flood Control Policy, naming Gilbert White as chairman. In 1966 the Task Force completed its report, A Unified National Program for Managing Flood Losses (House Document 465) which advocated a broader perspective on flood control policy including the need for land use management of flood hazard areas. The President then assigned the task of developing the framework to implement such a Unified National Program to the US Water Resources Council.

A Unified National Program for Floodplain Management

In 1975, the US Water Resources Council established the Federal Interagency Floodplain Management Task Force to carry out the responsibility of the President to prepare for the Congress any further proposals necessary to achieve the goals of floodplain management. The Task Force first issued a report in 1976 which sets forth a conceptual framework for floodplain management to guide Federal, state, and local decision-makers in carrying out a their responsibilities. The report, A Unified National Program for Floodplain Management, was updated in 1979 and again in 1986 by the Task Force which by then was chaired by FEMA after the Council was disbanded in 1982. The 1986 report built upon earlier reports, directives, and legislation and addressed the increasing loss of life and property caused by floods and the increasing interest in protecting the natural resources and functions of floodplains and wetlands. Because of the rapidly occurring changes taking place in water resources management and policy, both economically and environmentally, the Task Force commenced a revision of the Unified National Program document in 1993 to reflect these changes and to propose new ideas to better achieve the goals of floodplain management.

A Unified National Program for Floodplain Management 1994

The Federal Interagency Floodplain Management Task Force was finalizing a new conceptual framework and developing tangible goals to be achieved for the next 30 years just as the Mississippi, Missouri, Illinois, and other rivers were reclaiming their floodplain during the Great Flood of 1993. Although representing a diversity of Federal agencies with varying missions and goals, the members of the Task Force agreed that the 1994 document needed to explicitly state that the purpose of floodplain management encompasses two co-equal goals, 1) reducing the loss of life and property caused by floods, and 2) protecting and restoring the natural resources and functions of floodplains. The Task Force concluded that an effective means to achieve these goals was to promote a more comprehensive, "watershed" approach to floodplain management. The President underscored the significance of this approach in his March 1995, transmittal letter of the Unified National Program document to the Congress by stating:

[The Unified National Program] urges the formulation of a more comprehensive, coordinated approach to protecting and managing human and natural systems to ensure sustainable development relative to long-term economic and ecological health. Effective implementation of the Unified National Program for Floodplain Management will mitigate the tragic loss of life and property, and disruption of families and communities, that are caused by floods every year in the United States. It will also mitigate the unacceptable losses of natural resources and result in a reduction in the financial burdens placed upon governments to compensate for flood damages caused by unwise land use decisions made by individuals, as well as governments.

Sharing the Challenge: Floodplain Management Into the 21st Century

The Great Midwest Flood of 1993 focused the attention of the Nation on the human and environmental costs associated with decades of efforts to control the natural phenomena of flooding with structural

measures, unwise land-use decisions, and the loss and degradation of the natural resources and functions of floodplains. In part, this disaster can also be attributed to the single purpose decision-making process and fragmented planning at all levels of government, inconsistent statutory mandates, and conflicting jurisdictional responsibilities. Due to the magnitude of this flood disaster, the Executive Office of the President established a Floodplain Management Review Committee to determine the major causes and consequences of the flood and to conduct a comprehensive evaluation of the performance of existing floodplain management and related watershed programs. The Committee, comprised of staff from FEMA and other Federal agencies, prepared a report, Sharing the Challenge: Floodplain Management Into the 21st Century, which contains over 100 recommendations to improve floodplain management policies and programs at the national and state levels.

Coincidentally, the Federal Interagency Floodplain Management Task Force was finalizing the 1994 document, A Unified National Program for Floodplain Management at the same time. These two reports complement and reinforce each other by the commonality of their findings and recommendations. For example, both reports urge the formulation of a more comprehensive, "watershed" approach to managing human activities and natural systems to ensure the long term viability of riparian ecosystems and the sustainable development of riverine communities

Due to the high level of interest in implementing many of the recommendations of the "Sharing the Challenge" report and the stated goals and objectives outlined in the 1994 "Unified National Program" document, the Executive Office of the President (specifically the Council on Environmental Quality and the Office of Management and Budget) determined that a Floodplain Management Action Plan for the Nation, based on these two reports, was needed.

Table 1. Natural resources and functions of floodplains.

Water Resources

- Provide flood storage and conveyance
- Protect water quality
- Filter nutrients and process organic wastes
- Reduce erosion and sedimentation
- Facilitate aquifer recharge
- Reduce frequency and duration of high and low surface flows

Biological Resources

- Create a variety of habitats
- Privide breeding and feeding areas
- Support high primary productivity
- Preserve biodiversity and ecological integrity

Cultural Resources

- Contain significant historic sites
- Provide opportunities for environmental education
- Provide recreational and aesthetic amenities

The President's Floodplain Management Action Plan

The need to engender fundamental changes in Federal floodplain management policy to reduce flood losses while protecting floodplain resources has now been generally accepted. We must

recognize that flood hazard mitigation reduces the loss of life and property; prevents the loss of irreplaceable family possessions; reduces the economic and social impacts caused by floods throughout the impacted communities; maintains and improves floodplain resources and functions; and is cost effective. Furthermore, it must be emphasized that we can no longer afford the costs of flood disasters, and property owners must take greater responsibility for their actions and share the true costs associated with floodplain occupancy.

The Federal government can provide the leadership and facilitate coordination to encourage the public and private sectors to undertake actions to mitigate flood hazards, both routinely and in the recovery phase following a disaster. With the resources available we must begin to reduce, in real terms, the loss of life and property caused by the natural phenomena of flooding as well as prevent the continuing loss and degradation of the natural and cultural resources of our floodplains.

Although the Executive Office of the President has not yet completed its review of the final draft, the interagency committee developing the President's Floodplain Management Action Plan has made two significant recommendations to advance the goals of floodplain management . The first is to update and reissue Executive Order 11988 Floodplain Management (1977), to signify the Federal government's interest in providing leadership relative to achieving the goals of floodplain management. Second, that an interagency Water Resources Coordinating Committee be established to facilitate communication and cooperation among water resources agencies, and include floodplain and watershed management not just water supply and distribution issues. The structure and function of the committee will likely be similar to that of the original Water Resources Council (but without the budget). It is anticipated that this Floodplain Management Action Plan will be announced and released by the President in the Spring of 1996. When released, copies of the Plan can be obtained from the Executive Office of the President, The White House, Washington, DC.

Conclusion

Protecting and restoring floodplain lands and waters is in the best interest of the nation,, economically, socially, and environmentally. There is evidence that Americans, while still full of compassion and readiness to assist in times of true catastrophe, are becoming less willing to subsidize the costs of unwise floodplain occupancy as they become more knowledgeable about, and concerned for, the natural environment and ecological processes. The President's Floodplain Management Action Plan provides a vision for achieving the long-term goals of floodplain management which will help move the Nation towards a quality of life for every American that is sustainable into the 21st Century, and beyond.

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An Approach for Planning and Managing Monitoring Activities for Major Flood Events

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Introduction

In 1993, the Midwest floods highlighted, among other things, the need for water-quality monitoring during major floods. Although some of the issues in the 1993 floods were specific to the affected area,

some general conclusions can be drawn. Water-quality conditions related to major floods have the potential to affect both human and environmental health. Public concerns over water quality that were raised in the 1993 flood are tied to questions such as: "Is the water safe for human contact?"; "Is the water safe to drink?"; and "How will the fish be affected?" Existing routine plans for water-quality monitoring did not address such concerns adequately.

Human health as related to water quality can be directly affected by floods in several ways. Contaminants from both point and non-point sources have the potential to affect public water supplies. Contaminated water at a surface water supply intake can interrupt the function of a water supply system with accompanying public health and related economic consequences. Flood flows outside the channel have the potential to contaminate both public and private ground-water supplies. There are also concerns related to body contact with potentially polluted water in flooded areas.

In addition to its effects on human health, water-borne contamination has the potential to produce environmental damage that may affect endangered species, critical habitats, or agricultural activities. Each of these affects has the potential to produce unforeseen economic impacts that may not be evident to the casual observer.

The Mississippi River Flood of 1993 caused significant changes to the landscape throughout the Midwest and ultimately to the Gulf of Mexico. The flood sent large volumes of fresh water down the Mississippi River during a period of the year normally characterized by lower flows in the Mississippi, thus the timing of the flooding was a critical factor in determining the impact on the marine environment. The higher stream flow in the lower Mississippi River resulted in increased loadings of nutrients and agricultural chemicals, higher-than-normal oceanic surface temperatures, lower-than-normal surface salinities, changes in phytoplankton numbers and species composition, and increases in the area of low-oxygen bottom waters on the Texas-Louisiana shelf. The effects of the fresh water inflow were detected not only in the northern Gulf of Mexico but also at the Florida Keys and along the U.S. East Coast.

In order to respond to human and environmental health issues and concerns raised since the 1993 Midwest Flood, the Subcommittee on Water Quality, Interagency Advisory Committee on Water Data, established the Working Group on Flood Event Water Quality Monitoring (FEWQM), to serve as the principal mechanism for the development of a Federal plan for coordinating water-quality monitoring among federal, state, tribal, and local agencies during major floods. The Working Group developed a guidance document which addressed comments received on a draft document, especially those from areas affected by the 1993 Midwest Flood.

Several significant conclusions were drawn from the 1993 experiences. One conclusion was that the lack of an assured funding source for both Federal and State agencies impeded their abilities to sample during the early periods of the flood. Funds made available after the declaration of the emergency or disaster were too late to cover sampling during the early flood phases. As a result there was a concern that high contaminant concentrations that often flushed out during the first stages of a flood were missed completely. A second conclusion was that lack of a coordinated plan could result in duplicate sampling

by different agencies, while other sampling opportunities were missed. A third conclusion was that the turnaround time for analytical results, especially those that were related to public health, were too long. A final conclusion was that a coordinated effort was needed for dissemination of water quality information as soon as it became available.

Recommendations

As defined in the final guidance a major flood is one that is likely to prompt a Federal Disaster Declaration and a Federal response. The emergency components of the Federal government respond only after the President declares that an emergency or a major disaster has occurred and the Federal Response Plan (FRP) is activated. A disaster is defined as an event that, in the determination of the President, causes damage of sufficient severity and magnitude to warrant major disaster assistance by the Federal Government to supplement the efforts and available resources of states, tribal agencies, local governments, and disaster-relief organizations in alleviating the damage, loss, hardship, or suffering caused by the event.

Floods, unlike tornados or earthquakes, can have a slow onslaught. The initial flood may not require Federal assistance. However, the severity of the event may increase over time causing a major flood that warrants a Presidential disaster declaration. The following are the recommendations for each of the four flood periods identified in the final guidance:

- Before any flooding occurs (pre-flood), coordination among local, State, Tribal, and Federal emergency planning and water quality decision makers is essential to determine the needs and resources available for water quality monitoring activities during a flood.

- During a flood, existing resources at the local, State, and Tribal levels and Federal agencies at the field level are the primary sources of funding for flood monitoring activities.

- During a major flood that requires a Presidential Disaster Declaration, and that activates the FRP and the necessary Departments and agencies, coordination needs to occur between the local, State, and Tribal agencies conducting water quality monitoring activities and those Federal Departments and agencies that can assist with the effort.

- The post-flood period occurs after the flood waters recede and return to their normal seasonal levels. A post flood analysis and critique is vital to the success of future response efforts.

Action Plan Development and Implementation

Activities related to a flood can occur during four different periods (pre-flood, flood, major flood, and post-flood) that affect decisions made at the State, Tribal, local, and Federal levels for coordination, resource availability, and assistance from FEMA. Activities at ALL flood periods or phases require

collaboration at the community, state/tribal, regional, and federal levels.

Pre-Flood Activities

The pre-flood is defined as the time between the forecast and onset of the flood. During this period there are several activities which need to be coordinated and addressed. These activities include:

- Identify potential flood areas.
- Identify Federal agencies having flood water quality monitoring concerns in the potential flood areas and invite them to any flood emergency planning or implementation meetings or discussions.
- Identify water quality programs of Federal (local offices), State, Tribal, and local agencies.
- Discuss the relation between water quality monitoring efforts to address public health questions and long-term environmental health concerns.
- Prioritize sampling efforts that will provide the data required to answer as many public health and environmental concerns as possible.
- Identify the need for or interest in forming a Command Team or Command Center for water quality monitoring during a flood.
- Identify availability of resources; consider sharing of resources to the extent possible among agencies.

Flood Activities

The flood is defined as the period when flooding is occurring. Activities which need to be addressed during this time include the following:

- Decide on when to implement the monitoring plan in connection with any other emergency event activities.
- Implement the monitoring plan, if necessary, which includes:
- Activating a command center;
- Collecting and analyzing samples; and

- Evaluating and disseminating data and information.
- Consider advising the Governor to request Federal assistance for a disaster situation.

Major Flood Activities

A major flood is one that is likely to prompt a Federal Disaster Declaration and a Federal response. During a major flood the following activities occur:

- The President declares an emergency.
- The Governor appoints a State Coordinating Officer (SCO).
- The President appoints a Federal Coordinating Officer (FCO).
- Implementation of the Federal Response Plan; Federal support agencies activated.
- Opening of operational disaster field office with federal support agencies present.
- Coordination and integration of water quality monitoring plan with emergency support function activities.

Post-Flood Activities

The post-flood is defined as the period when waters recede to normal seasonal levels and flood related water quality monitoring activities are no longer necessary. During this time the water quality monitoring group does the following:

- Analyzes the data and considers further activities or studies.
- Critiques the pre-flood and flood activities.
- Modifies the water quality plan as needed.
- Assigns writing responsibilities for report on water quality as related to flood.
- Disseminates the report as related to the flood.

Resources

The availability of funding for the period between the forecast of a flood emergency and a Presidential disaster declaration is a major issue. Pre-flood activities are assumed to be funded within existing local, state, tribal, and federal agency budgets. During a major flood, water quality activity funding can be requested by States from FEMA following the declaration of an emergency by the President. The planning group should determine what monitoring is needed within the watershed during each flood period and request funding from the State and federal agencies as applicable.

In its final guidance, the working group also recommended two alternatives for obtaining funding for the period between the flood forecast and a Presidential disaster declaration of emergency, which could be considered at the federal level. These alternatives include:

1. Establishing a permanent revolving fund for flood-event water quality sampling within a designated federal agency; or
2. Amending existing legislation such as the Stafford Act so the FEMA could reimburse federal, state, tribal, or local agencies for pre-declaration flood water quality monitoring activities.

Sample Collection & Safety Issues

Several issues concerning sample collection and safety need to be addressed during flood water quality monitoring planning and implementation. With respect to sampling, the number and types of constituents for sampling need to be identified. To assist this process, the guidance provides an approach for determining the major water quality monitoring constituents by land uses. Samples are obtained to evaluate the chemical, physical, and biological quality of the water. Also, the sampling sites for both surface and ground water need to be identified. During flood periods, ideal sites might not be accessible and alternates need to be considered. For sampling, both the sampling techniques and types of equipment need to be determined for both the surface water and ground water samples. Sediment sampling should also be considered. To the extent possible, quality control practices should be followed. It is recommended that a minimum of 10 percent of the samples analyzed be quality control samples. In particular, any deviations from standard practices should be documented in field notes.

With respect to health and safety, the monitoring group needs to have all appropriate immunizations and be trained on the use of boating equipment and first aid. When sampling from bridges and cableways a minimum of three people are required at all times during floods. Because of the high flood velocities, sampling will probably be done off the downstream side of the bridge; thus, while two people are sampling or processing, the other person must be watching upstream, looking for debris and other objects that might be a danger to personnel and equipment. If any hazardous materials or wastes are found by the sampling team, certified personnel should be contacted.

All data collected must be reviewed and the results released as soon as possible because during the flood period there is an intense interest in any data bearing on public health issues. Until the data can be thoroughly checked, it should be released as "unpublished, subject to revision." For the release of flood-related information, one spokesperson should be appointed by the command team leader. This will help

to control the release of information in a coordinated manner to the media and general public.

Federal Implementation of the Final Guidance

For future major flood events, the working group plans on working with the primary agencies responsible for the relevant Emergency Support Functions (ESFs) which could consider and recognize any water quality monitoring activities. Of the 12 ESFs identified in The Federal Response Plan developed by the Federal Emergency Management Agency (FEMA, 1993), three functions relate to the monitoring activities. The lead and other agencies assigned to work on ESF #3 - Public Works and Engineering, ESF #8 - Health and Medical Services Annex, and ESF #10 - Hazardous Materials Annex would be encouraged to incorporate water quality monitoring activities including appropriate sampling as recognized activities within the scope of their functions.

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Managing Watersheds To Reduce Flood Losses

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By itself, the decision to drain and tile a farm field, fill a wetland or build a parking lot has little measurable impact of flooding. But when combined with thousands of similar decisions over hundreds of years, the impact can be devastating.

Across the nation, thousands of seemingly unrelated decisions have dramatically increased the rate at which water moves off the surface of the land. Consequently, flood losses have more than doubled since 1951, when adjusted for inflation, to more than $3 billion annually despite massive federal investments in levees, dams and other structural flood control solutions. Rather than address the causes of flooding, our flood control policies continue to treat symptoms by building levees and dams that temporarily protect some communities at the expense of other poorer floodplain communities. Rather than use the natural flood control functions of floodplains and watersheds to store and slowly release floodwaters, levees have increased flood losses by increasing and accelerating flood waters and by creating a false sense of security that has encouraged floodplain development.

The nation's floodplains and watersheds have long been altered to drain as quickly as possible to reduce property losses. As far back as the Swamp Land Acts of 1849, 1850, and 1860 which resulted in the transfer of nearly 65 million acres of wetlands to expedite their drainage federal programs have created powerful incentives to eliminate the natural flood control functions of wetlands and hydric soils. As mainstem flooding inevitably increased, private and public funds were spent on levees and dams to compensate for growing floodplain losses.

Ironically, images of volunteers placing sand bags on levees, presumably fighting Mother Nature, are more accurately images of upstream and downstream communities at war with each other. In floodplain communities, embattled public works agencies and private levee districts continue to fight losing battles against past and present agricultural and urban land uses that increase overland flow. These communities

have spent millions of dollars to build structures to temporarily protect vulnerable communities and, more recently, have begun spending millions more to modify older structures to compensate for ongoing changes of the landscape. In some years, they win the fight. But, as uplands continued to be drained for urban and agricultural uses, inundated floodplain farmers and communities increasingly find they are losing the war against their upstream neighbors.

At the same time that overland flow has increased, more and more people are moving into floodplains. One reason is the language of risk terms like "floodplain" and "onehundred year flood" fails to portray the real costs of floodplain development. Another reason is the National Flood Insurance Program, created in 1968 to reduce spiraling disaster costs, has instead acted a financial safety net for risky development. By the late 1970s, 3.5 million to 5.5 million acres of floodplain land had been developed for urban use nationally, including more than 6,000 communities with populations of 2,500 or more. Annual population growth in these floodplain areas was between 1.5% and 2.5%, roughly twice that of the country as a whole.

The human costs of our failure to properly manage our floodplains and watersheds are compounded by the environmental costs of short-sighted structural solutions. Linkages between the river and its floodplain are critical to maintaining the long-term health of riverine systems. Most of the plants and animals inhabiting river floodplain systems have adapted to the river's flood pulse: the annual advance and retreat of floodwaters onto the floodplain. During periods of highwater, fish and wildlife migrate out of the channel and onto the floodplain to use newly available habitat and resources. As floodwaters recede, nutrients and organic matter from the floodplain are transported into the river. By occupying large areas of bottomlands, rivers ensure that some portion of the floodplain would meet the habitat requirements for a wide variety of species during high flow periods.

In addition to providing fish and wildlife access to seasonally inundated spawning and nursery habitat, these river-floodplain interactions also trigger the biological and chemical transformations that make food available higher up the food chain. Like all river systems, energy flows from primary producers (plants) through an invertebrate consumer community to species consumed and enjoyed by humans (fish and waterfowl). When floodwaters inundate floodplain habitats, energy stored in floodplain plants is released to the aquatic environment. The construction of levees eliminates many of these natural processes.

Dams constructed to reduce mainstem flood losses have also had a dramatic impact on the nation's river systems. In addition to eliminating many of the fluvial processes by which rivers create and maintain habitat, dams block the downstream flow patterns of water, sediment and nutrients, block the migrations of aquatic organisms, and dramatically alter water quality. Just as the release of cold, deoxygenated water adversely affects many native organisms, warm, murky reservoirs often favor introduced or predator species, affecting the size and diversity of fish and wildlife populations. Flood control dams often have dramatic affects on distant ecosystems. Sediment blocked behind the dams on the Missouri River, for example, is no longer available to maintain the Mississippi River Delta, which is losing more than 50 miles of coastal wetlands to erosion each year. In combination, dams and levees designed to compensate

for increased mainstem flooding have contributed to the decline of more than one third of America's fish species, which are disappearing at a more rapid rate than land-based or avian species. Between 1979 and 1989, 10 species of freshwater fish became extinct, and an additional 139 species have become endangered, threatened or listed as "of special concern."

Meeting the needs of floodplain communities is not inconsistent with protection of the natural environment. Restoring watershed and floodplain functions would simultaneously reduce flood losses, restore lost fish and wildlife habitat, and reduce erosion and non-point-source pollution. Although communities have been managing floodplains and watersheds for more than two decades to address concerns about water quality, few communities have managed watersheds to reduce flood losses. But the Great Flood of 1993 a flood of supposedly biblical proportions shattered the nation's faith in structural flood control. Rather than returning to the river's edge, thousands of flood victims voluntary relocated more than 8,000 homes and businesses to higher ground, the largest relocation since Noah. More than 90,000 acres of flooded farmland were voluntarily converted to wetlands.

Rather than calling for higher levees, a task force of national flood control experts concluded that upland watershed treatment and the restoration of upland and bottomland wetlands should be undertaken to reduce flood stages. The Army Corps of Engineers, in the agency's Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri River and Tributaries, also found that "upland retention and watershed measures directly influence the volume and peak runoff generated from rain fall event" and concluded that higher levees would simply inundate downstream communities. In contrast to structural flood control solutions which often have heavy, poorly calculated environmental costs managing watersheds and floodplains to reduce flood losses is not only less expensive than levees and dams but also provides important secondary benefits: improved water quality, habitat restoration, and enhanced recreation, tourism and scenic values. Many of the techniques that can be used to reduce overland flow maintaining trees, shrubbery, and vegetative cover, terracing, slope stabilization, using grass waterways, and contour plowing and other tillage practices have already been used by landowners to reduce non-point solution pollution and erosion. Several land treatment measures involve little additional cost to the farmer, and some, such as no till or minimum tillage, actually reduce costs.

Congress has already taken steps to reform our outdated flood control policies by reforming flood and crop insurance programs, and by using flood insurance funds to relocate vulnerable homes and businesses. In 1994, Congress failed to reauthorize the Water Resources Development Act, the Corps' authorizing legislation, for the first time in more than a decade due to significant philosophical differences over structural flood control. And, recent flooding in the Northeast and Northwest has once again forced the nation to question some underlying assumptions about the management of our nation's rivers. Roles and responsibilities that have been established over decades suddenly seem out of date. Practices designed to reduce flood losses are, in some cases, thought to have made things worse.

Whether Congress will give communities the tools and incentives they need to manage watersheds and floodplains to restore natural flood control functions remains to be seen. Federal programs to reduce erosion and non-point source pollution programs that might also be used to address changes in overland flow are poorly coordinated and underfunded. In the Upper Mississippi River Basin, for example, the

federal and state agencies that administer the easement, acquisition, and erosion and non-point source pollution control programs rarely conduct regional or watershed-wide planning and even more rarely consider the potential benefits of flood loss reduction while conducting their programs.

To successfully reduce flood losses, policymakers should take three steps: 1) link cost-sharing for federal flood control projects to strong state and local floodplain and watershed management to reward good behavior; 2) increase technical assistance by federal agencies to communities engaged in active watershed-wide planning; and 3) require federal agencies like the Corps of Engineers to develop and model watershed management alternatives during their decision-making processes.

Rather than build levees and drain wetlands in isolation, people living within a single drainage basin must begin to share responsibility for their land-use decisions. The federal government can lead by example, but state and local government must be given the tools and incentives they need to properly manage their floodplains and watersheds.

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Kagman Watershed, Saipan, CNMI

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Introduction

The planning and implementation of the Kagman Watershed project demonstrates the importance of using the watershed approach to identify and address multiple problems, opportunities, and concerns and the advantages of using broad-based partnerships to plan and implement watershed projects.

The Kagman watershed is a 3,750-acre peninsula on the eastern shore of the island of Saipan in the U.S.-affiliated Commonwealth of the Northern Marianas Islands (CNMI). (Figure 1) Saipan is located approximately 120 miles north-northeast of the island of Guam.

In the mid-1980s to the early 1990s, the rapid pace of economic development activity in the CNMI, spurred primarily by Japanese investments, outstripped the checks for rational development of the economy and wise use of its natural resources. The viability of commercial agriculture on Saipan suffered from escalating land values that fostered conversion of farmland to other uses, plentiful employment opportunities in service industries, and increased competition for water resources. Meanwhile, opportunities existed to expand the market for locally-grown produce, for increased capital investment in more productive and efficient farming methods, and for the development and dissemination of environmentally sound farming practices. The CNMI government professed a policy of expanded commercial agriculture and self-sufficiency in those crops that can be economically grown in Saipan.

The Kagman watershed contains the largest and most important truck crop farming area on Saipan which produces approximately one-half to three-quarters of crops, such as taro, beans, bell peppers, and melons, grown on the island. The average size of the farms is 2.5 acres, although several are greater than ten acres in size. Despite their small size the farms are viable commercial operations and provide an important contribution to economic activity in the commonwealth.

The resource problems that prompted the need for project action were agricultural flooding and inconsistent and inadequate water supply affecting 340 acres of publicly and privately owned cropland. The two local organizations that were seeking to resolve the resource problems were the CNMI Department of Natural Resources, which operates the 220-acre Kagman Commercial Farm Plots, and the Saipan and Northern Islands Soil and Water Conservation District (SWCD). The Kagman Commercial Farm Plots is the only government-owned farming area on Saipan. The SWCD recognized the importance of maintaining commercial agricultural activity in the area and pursued actions to protect and enhance farming opportunities in the Kagman watershed.

Planning and implementation assistance from the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, under the authority of the Watershed Protection and Flood Prevention Act, Public Law 83-566, was requested by the Department of Natural Resources and the SWCD in 1986. The watershed plan and supporting Environmental Impact Statement were finalized in September 1993.

Watershed Plan

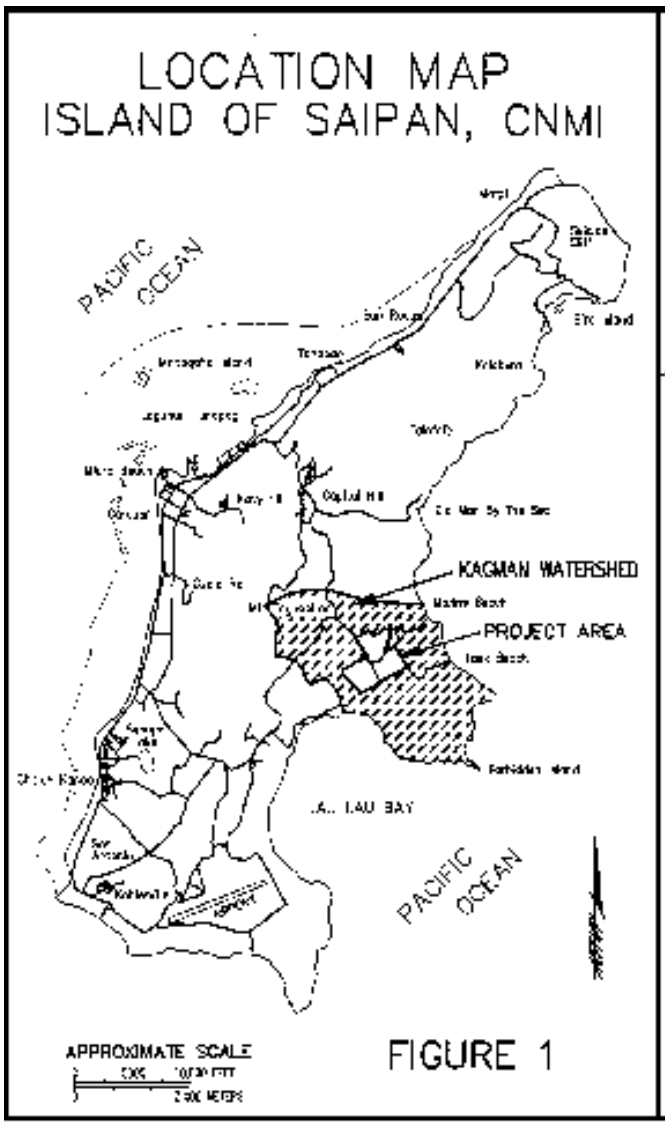
Through a coordinated planning effort, led by the SWCD and the NRCS's CNMI Field Office, a plan for agricultural flood prevention and irrigation water supply was developed. The plan includes a system of grassed waterways to intercept and safely convey floodwater through the crop area and an irrigation water storage and distribution system. (Figure 2)

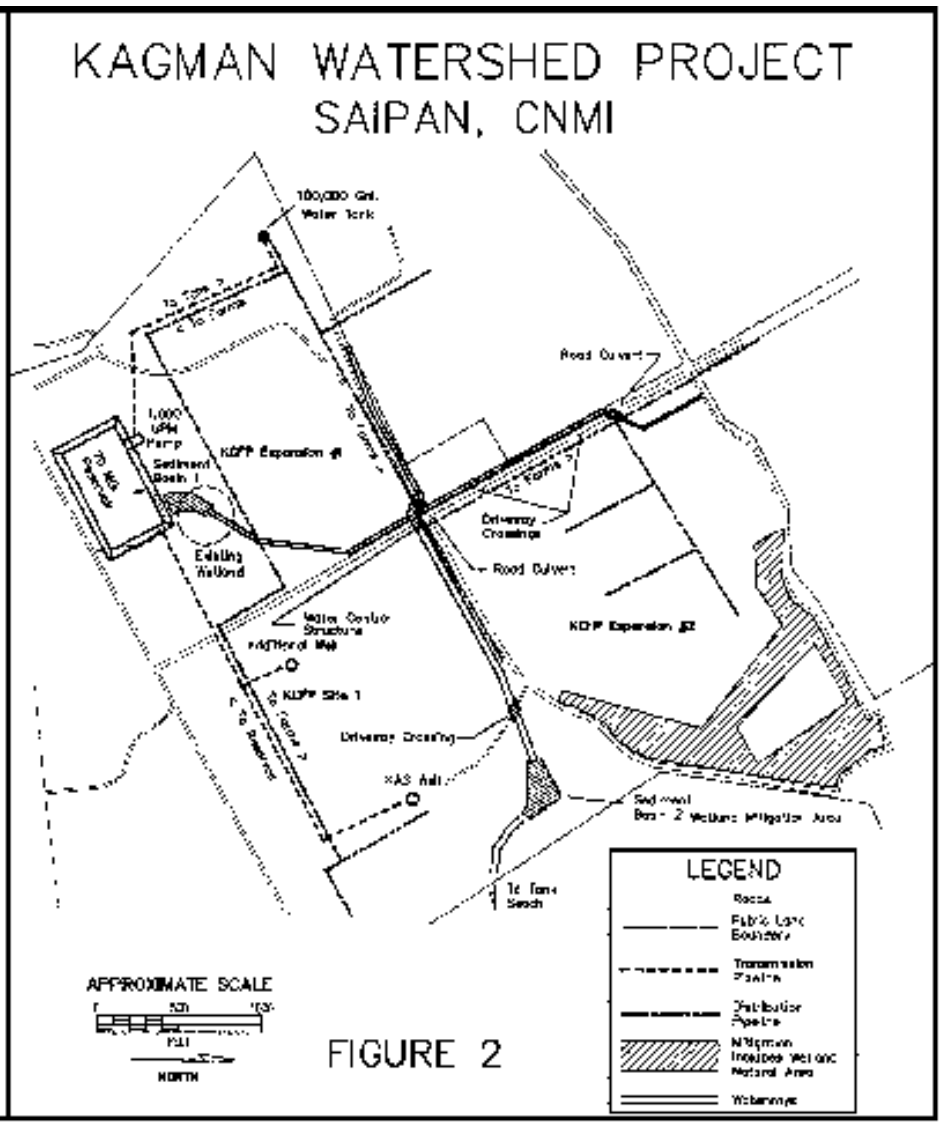
The waterways were designed to safely accommodate the peak discharge for the 25-year, 24-hour storm. Maximum discharge capacities in the waterways was 1,140 cubic feet per second. Two outlets for the storm runoff were planned_to onsite storage for irrigation supply during the dry season and discharge of the excess to the ocean via a stream running to Tank Beach.

Supplemental irrigation is needed during the January through June dry period to ensure successful crop production. Both surface and groundwater sources of irrigation water supply were evaluated. An existing island-wide groundwater investigation effort by U.S. Geological Survey and the CNMI government was expanded with NRCS funds to characterize the aquifer in the Kagman Peninsula for agricultural use. The resulting USGS Water Resources Investigation Report concluded that the sustainable yield of the underlying basal aquifer was insufficient to provide adequate irrigation water at acceptable salinity levels. Transfer of water from outside of the watershed was not a viable option because water supply was severely limited throughout the island.

Storage for runoff collected within the watershed was located at an infrequently-used limestone quarry within the farming area. When shaped and lined with pneumatically-applied mortar, the quarry will yield a storage volume of 70 million gallons. Two or more basal wells, to provide 70 gallons per minute, will be incorporated into the irrigation system to augment runoff and to provide a limited emergency backup supply. The distribution system will consist of a pump at the reservoir to transfer water via a 2,140-foot long transmission pipeline to a 100,000 gallon hill-top storage tank connected to the distribution system. The agricultural water system will service 59 farms with a total of 263 acres at a 95 percent reliability.

The project installation cost was estimated to be $4,753,000 in 1993. The average annual benefits of $647,500, due to reduced flood damage and additional crop cycles during the dry season, exceeds the average annual cost of $512,300.





Concerns

Three bird and one sea turtle species appearing on the U.S. Threatened or Endangered Species List are known to inhabit the area in or near the project. Assistance from the CNMI Division of Fish and Wildlife and the U.S. Fish and Wildlife Service was invaluable in assessing impacts and developing mitigation strategies.

The design of the sediment basin leading to the reservoir could not avoid disturbance of a small wetland with an area of 0.07 acres. The Kagman South wetland was determined to provide a secondary quality habitat to the endangered Mariana Common Moorhen, one of the principal species targeted for recovery in the CNMI. A mitigation alternative was developed through coordinated efforts involving NRCS, DNR, CNMI Division of Fish and Wildlife, U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service. The Wetland Mitigation Plan set aside approximately 25 acres at the north end of the government farming area to remain in forest as a buffer and for construction of two wetlands totalling 1.78 acres. The created wetlands will include an existing wetland of 0.11 acres. The constructed Kagman West wetlands will be adjacent to and hydraulically connected to the existing Kagman North wetland which provides one of the most important habitat sites for the moorhen on Saipan. The U.S. Fish and Wildlife Service provided guidance and assistance with the constructed wetland design. Features, such as interpretive trails and observation blinds, have been incorporated into the wetland design to help develop awareness, especially among children, of wetland and wildlife values.

The Nightingale Reed Warbler, a listed endangered species, was identified in parts of the forested grazing area of the Kagman Commercial Farm Plots to be converted to cropland. Retention of a contiguous forest band adjacent to other forested property, as provided in the 25 acres for the wetland mitigation plan, will continue to provide Nightingale Reed Warbler habitat within the project area.

Sediment runoff to the ocean from construction and farming activities could adversely affect the nearshore environment at Tank Beach, an important foraging and nesting habitat of the endangered Green Sea Turtle. Sediment yield calculations, using the Universal Soil Loss Equation and sediment routing procedures, demonstrated that the future sediment discharge with the project, which will include soil conservation practices on the farmland and project sediment basins, was less than without the project. Implementation of soil conservation and water quality improvement measures would improve Green Sea Turtle habitat at Tank Beach.

Interaction with other projects was evaluated. Two projects located on the Kagman Peninsula were determined to have significant interaction with the watershed project. A resort and golf course project to the south and west of the agricultural area to be developed by the Shimizu Corporation would need irrigation and potable water resources. Access to the resort and golf course would be through the resort area.

Through the efforts of the SWCD, a cooperative relationship was established with the Shimizu Corporation project, despite the need by the two planning projects for the same water resources. Hydrologic data and analysis were freely exchanged between NRCS technical planners and Shimizu Corporation consultants. Well testing data by the Shimizu Corporation was used for the placement of the watershed project's wells. The SWCD received a grant from the Shimizu Corporation to be used toward their costshare for project implementation. Recently the Shimizu Corporation provided excavation and earthmoving assistance for construction of the mitigation wetland in return for the excavated material to be used in their golf course construction.

The shortage of developable public lands on Saipan and the lack of effective land use controls, during the early years of project planning, caused the Kagman farming area to be designated for a variety of uses by various CNMI agencies. Some of the intended uses included solid waste disposal, a prison complex, and residential homesteads. Through the efforts of the local sponsoring organizations and the influence that the federally-assisted project may have provided, the farming land in the Kagman area was protected from being converted to other uses.

The residential homestead program awards one-quarter acre lots to Chamorro and Carolinian residents of CNMI. The Unai Alaihai Subdivision will contain as many as 1,869 homestead residences, two schools, commercial areas, and public facilities on approximately 450 acres surrounding the north and east borders of the project area.

A thorny issue associated with the development of the residential subdivision was the source of water supply. The farmers feared that agricultural water would be appropriated by the Commonwealth Utilities Corporation (CUC) for domestic supply to the subdivision. A Memorandum of Understanding was developed and executed between the project sponsors and the CUC reaffirming that the water supply developed by the Kagman Watershed project will be used for agricultural purposes.

An archeological and historic properties inventory was conducted in July 1993 which identified seven historic sites related to pre-World War II Japanese sugar cane cultivation or post-war American military activity. For the most part, the historic sites will be avoided through rerouting of the irrigation distribution pipeline. One site where the storage tank will be located will be recovered through field documentation.

The pre-World War II Japanese occupation, wartime combat operations, and U.S. military control for nearly a decade following the war has left the Kagman area scattered with ordnance and other wartime materiel. Project planners coordinated activities with the U.S. Army Corps of Engineers' Environmental Restoration Program to characterize a dump

site within the project area and a Japanese fuel cache upstream of the project area. Remediation plans for the two sites were prepared and will be implemented by the Corps of Engineers program.

Conclusion

The consultation and coordination activities for the Kagman Watershed Project were considerable. The issues addressed and the planning environment were quite different from usual PL-566 project planning and illustrate the adaptability and flexibility of the program. The planning process and sound principles as well as the vision and support of the local sponsors remained the foundation upon which the Kagman Watershed plan was developed.

By enlisting the early support of partners such as the U.S. Fish and Wildlife Service and the Corps of Engineers, the Kagman Watershed project will be able to enhance wetland, nearshore, and forest habitat for endangered species. Through a private-public partnership the sponsors have been able to leverage their limited resources toward implementation of the project and their vision of productive commercial agriculture in the Kagman watershed.

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Agricultural and Environmental Sustainability: A Watershed Study of Virginia's Eastern Shore

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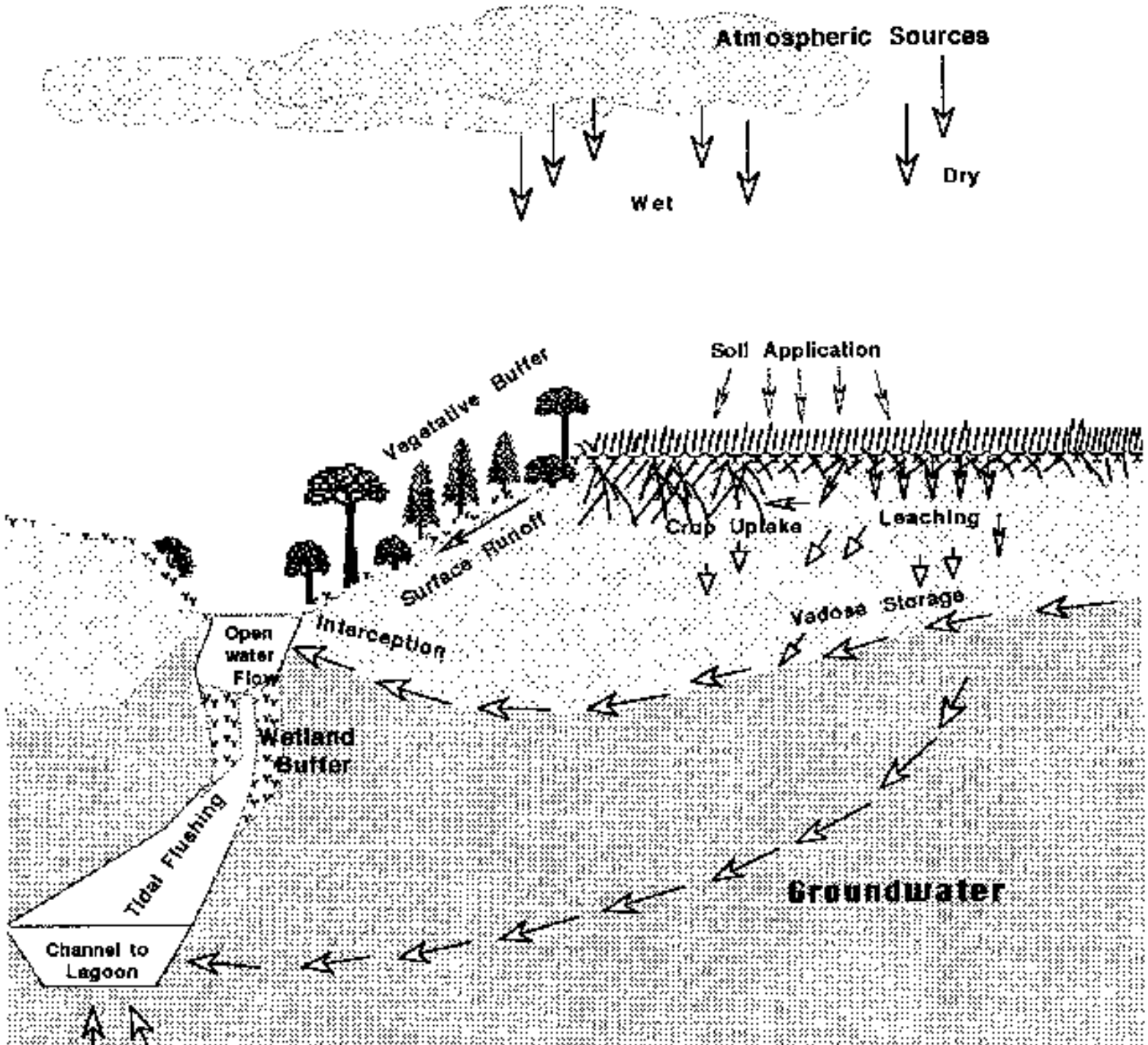
Introduction

Bounded by the Atlantic Ocean to the east and the Chesapeake Bay to the west, Virginia's Eastern Shore is a rural region of the coastal plain that has long relied on agriculture, forestry, and fishing to support its economic base (e.g., Ellis, 1986). The east side (seaside or oceanic side) of the Eastern Shore peninsula has a barrier island and inner coastline separated by a coastal lagoon system. The upland areas are forested or in agriculture, and drain to the seaside through numerous, small, first-, and second-order watersheds. These small watersheds are the fundamental building blocks of the seaside ecosystems impacting adjacent barrier island lagoons on this coastline.

Agriculture is the predominant land use in this region and is thought to be a source of contaminants. There are perceived conflicts between Eastern Shore communities that rely on fishing and those that farm the land. Fishermen believe agricultural runoff has been largely responsible for degraded fisheries. Much of the nitrogen in coastal estuaries associated with rural agricultural landscapes originates in the upland terrestrial systems from non-

point sources (Office of Research & Development, 1974) and to a lesser extent precipitation inputs (Paerl, 1975). The shallow unconfined aquifers of Virginia's coastal plain display characteristics that are conducive to groundwater contamination and its subsequent transport into aquatic habitats, including shallow water table depths, highly permeable sandy substrates, and low elevation and topographic relief. It has been estimated that groundwater contributions to non-tidal streams account for up to 80% of the stream flow on the Delaware, Maryland, and Virginia, Delmarva Peninsula (Bachman, et al., 1992). The consequences to coastal marine systems include eutrophication and possibly reduction of seagrass beds and associated fauna (Valiela, et al., 1990).

Water quality issues, both surface and groundwater, in these seaside watersheds and coastal lagoons are of central importance to both agricultural management and environmental quality, nationally as well as on Virginia's Eastern Shore. It is necessary to understand the uptake capacity of agricultural crops and other watershed flora (e.g., for nutrients), and the holding capacity of watershed sediments, as conceptually illustrated in Figure 1, in order to determine how these watersheds function either as a buffer protecting water quality of adjacent lagoons, or as a source for contaminants to the lagoon system, enhancing eutrophication.



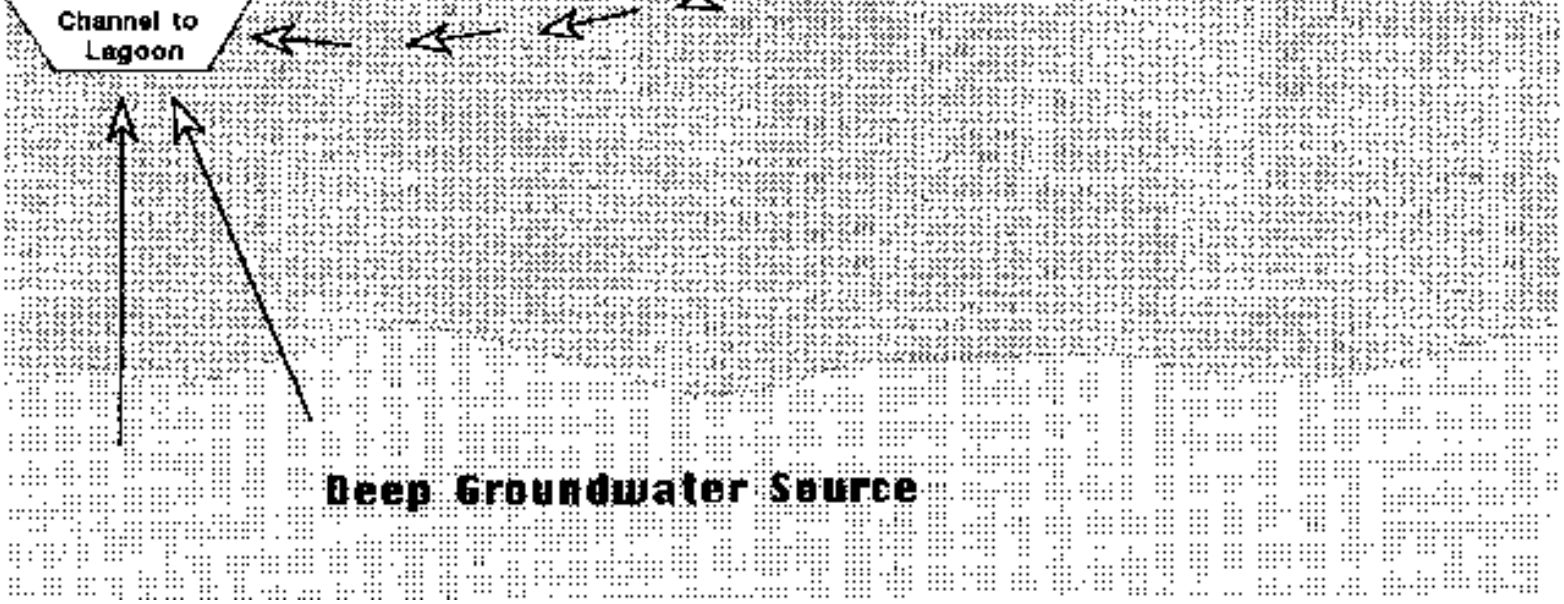


Figure 1. Conceptual diagram illustrating the sources, buffers and pathways of water and potential pollutants in transit to a coastal barrier lagoon.

Study Approach

The research described here is taking a holistic approach to detect and quantify land-derived contaminants in surface and groundwater, by combining the talents of experts from a number of different disciplines. The ultimate goal is to develop management practices that will ameliorate production and adverse effects from agricultural contaminants on coastal ecosystems. The research team, consisting of an agricultural scientist, a groundwater biologist, a geologist, a coastal ecologist, and an ecosystem scientist, with participation from a local farmer, has been brought together to achieve three primary purposes. First, to explain in an ecosystem fashion, the interactions between surface and groundwater quality as related to agriculture, and other activities on the landscape. Our approach integrates the dynamic biophysical factors that influence transport of water to the coastal lagoon system (Figure 1). Second, to measure the impact of agricultural activities on the barrier island lagoon system with the ultimate intent of being able to duplicate predictions for other similar coastal watersheds. Third, guided by our results, to develop future research that will evaluate alternative agricultural management strategies for their effectiveness in decreasing potential contaminant impacts on upland surface and groundwater and lagoonal water quality.

This project distinguishes itself from previous watershed studies by examining agriculture-groundwater interactions and the importance of groundwater and surface runoff inputs, in contrast to those dominated by surface runoff alone. In addition, unlike other studies done on watersheds dominated by clay and silty loam substrates, this study is concentrated on landscapes underlain by well-drained, fine- to coarse-grained, quartz sand. These sandy landscapes are typical of the northern part of the Atlantic and Gulf Coastal Plain groundwater region defined by Heath (1984). This study is also unique in that it couples an analysis of nutrient input, hydrologic and physical processes influencing transfer of contaminants through the surface and groundwater, and discharge to coastal waters, with eventual cultural alternations on the landscape to reduce contaminant transport.

Study Results

Specific research goals of this project included the following:

- Quantify contaminant loading patterns for a seaside agricultural watershed that drains into a barrier island lagoon on Virginia's Eastern Shore.

- Determine resulting changes in the quality of the groundwater, non-tidal/tidal creek, and the seaside lagoon system from agriculture activity in this watershed.

- Define process dynamics influencing land-derived contaminant flows through the seaside watershed ecosystem, including sources and sinks that contribute to system output.

- Measure ecological impacts on the lagoon system from surface and groundwater discharge.

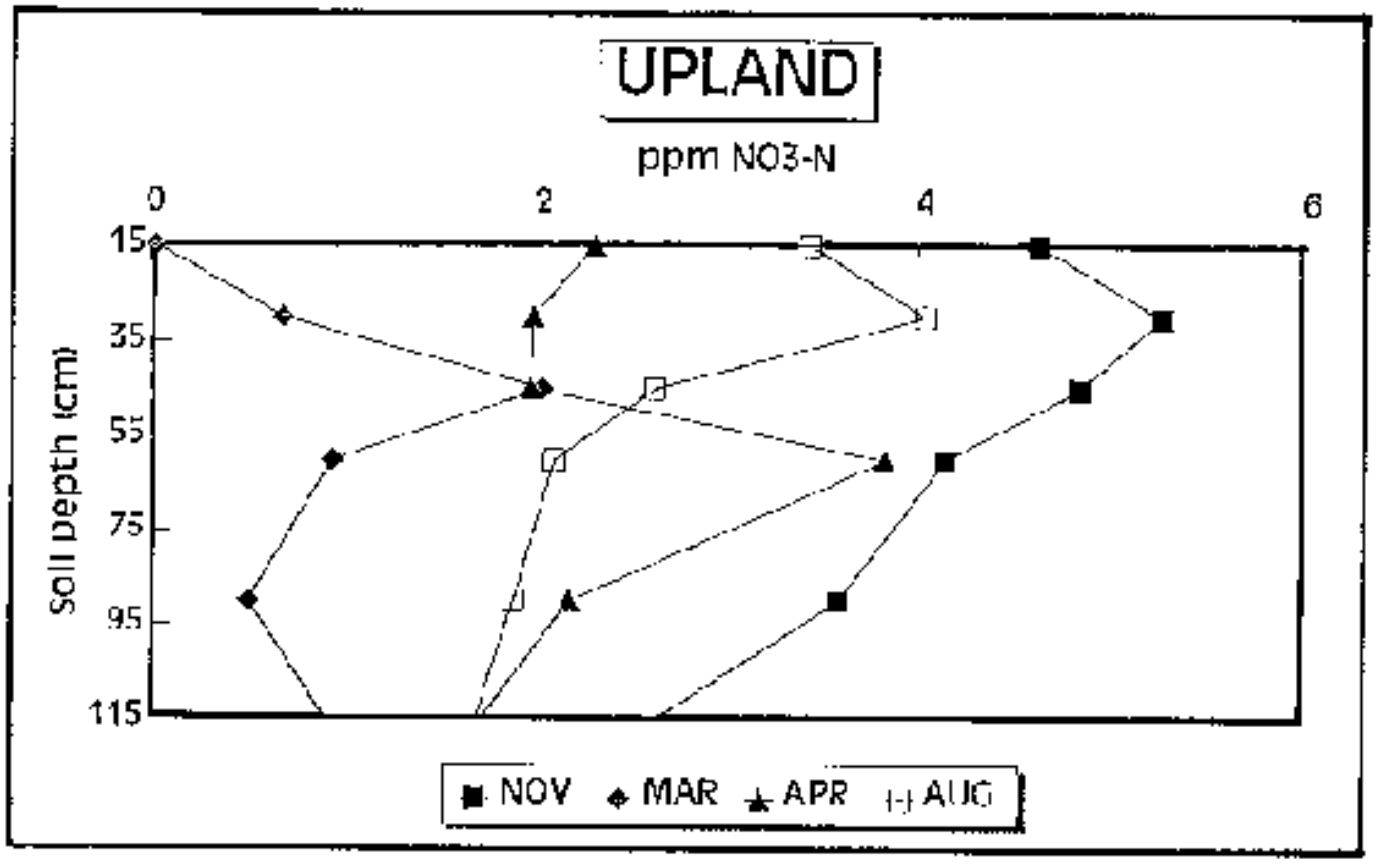
The Greens Creek watershed, the focus of our study, is relatively typical of first-order watersheds bordering the barrier island lagoon system along the Eastern Shore of Virginia. It possesses fluvial, estuarine, and lagoonal components, which are partially influenced by groundwater interception, surface runoff, and tidal hydrology. Between the upland recharge plain and the seaside barrier islands there is a stream valley, a scarp zone, a hammock/wetland zone, a coastal lagoon zone and a tidal inlet. The Greens Creek watershed has agricultural activities occurring in the upland, scarp, and hammock/wetland sections.

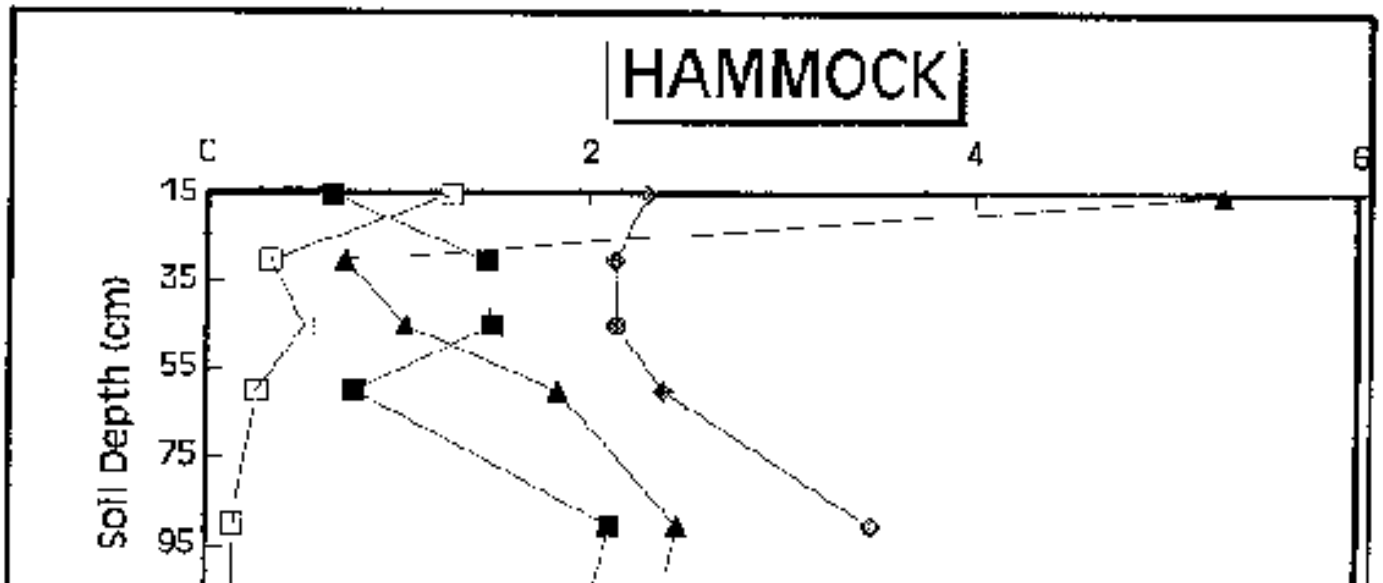
Drainage patterns on the upland sections of the watershed surface are dendritic and permeable allowing the entrance of contaminants into the unconfined aquifer. Transfer through the hammock section is affected by the balance between mass transport, diffusion, and tidal exchange, as influenced by oceanic processes. The lagoon of this watershed, like many estuarine areas, is subject to dynamic changes and episodic shifts in ecological processes (e.g., Fong, et al., 1993; Comin and Valiela, 1993). Only in recent years has the significance of this terrestrial input to estuarine systems come to be appreciated (e.g., Valiela, et al. 1992). Greens Creek is the first site in our study area where groundwater containing terrestrial inputs mixes with the lagoonal ecosystem.

During the last two years our interdisciplinary research team has made important contributions to the initial understanding of Eastern Shore agricultural impacts on water quality. Between 1993-1994, a network of 78 surface stations and wells were established in order to delineate the watershed with respect to groundwater flow patterns and to obtain preliminary determinations on the quality of water contained in and leaving the system. Transects of wells were established from the headwaters of Greens Creek to the spillway at the creek's tidal end. Discharge measurements at creek transect sites have defined groundwater recharge and discharge areas of the watershed. The main recharge area is in the extreme upland area, while discharge increases dramatically as one moves seaward. Observations indicate that groundwater is the principal source of water for Greens Creek which maintains flow throughout the year in its lower portions. Discharge is also received from deep sources, as well as from precipitation.

The nutrients contained in rainfall represent a probable contribution to the overall nutrient budget of this system with average concentrations of 62.6 umol/L of dissolved inorganic nitrogen and 0.83 umol/L of dissolved inorganic phosphorus measured during 1994-95. Soil nitrate concentrations of agricultural fields in the upland component of the watershed (Figure 2) have shown a pattern of build-up in shallow sediment layers during the fall, associated with harvest of soybean, nitrogen-fixing crops. After the winter recharge cycle, soil nitrate concentrations at the shallower soil levels were substantially lower, with movement of nitrate peaks down through the soil layers during the spring. This migration was routinely observed to coincide with spring rains and associated leaching. Increased nitrate in the shallow soils in April was related to fertilization of the wheat fields. The position of the highest concentration of soil nitrate shifted from 15-30 cm depth in November, to 45 cm depth by March, and to 60 cm depth by April, suggesting that there was significant residual of crop-applied fertilizer nitrogen occurring on this

watershed from agriculture activities. The high nitrate levels in August further reflected leaching action while increased levels in the top 25 cm were the result of wheat harvest with associated breakdown of crop residue, as well as nitrogen fixation by the July planted soy bean crop. Both the soil nitrate concentration and the distribution with depth after harvest are consistent with previous studies on silty clay loam soils (Brinsfield and Staver, 1991; Varnel and Peterson, 1990). The soil nitrate pattern within the hammock was not consistent with observations in the upland portion of the watershed (Figure 2). In fact, there seemed to be an indication that as measurements were taken from November through April down through the soil depths, nitrate accumulation increased in shallow depths over time, rather than the leaching pattern and downward movement observed in upland areas. These observed dynamics could be related to the presence of a shallow water table in this region of the watershed during wet months, trapping nitrogen in the shallower soils. In contrast, during August dry periods the water table is much deeper and patterns of nitrogen leaching down through the soil were observed (Figure 2), similar to patterns in the upland region.





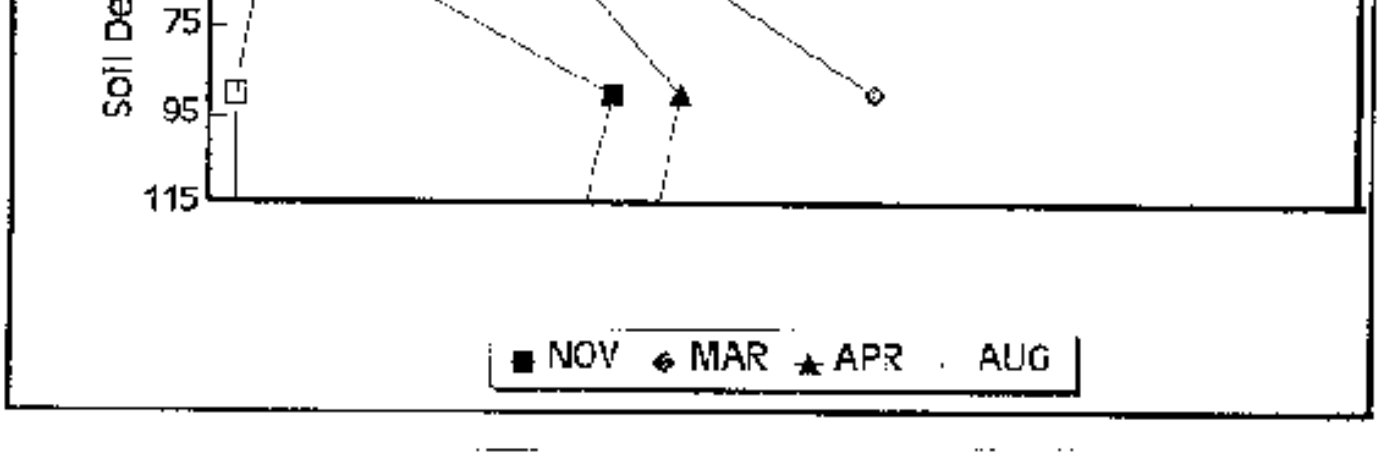


Figure 2. Soil profiles for nitrate in upland and hammock sites over four seasonal sampling periods.

Groundwater quality measured at selected wells exhibited the pattern of nitrogen enrichment underlying the agricultural portions of the watershed. For example, total dissolved inorganic nitrogen in the groundwater coming from under agriculture fields showed an average of 228.0 umol/L while these same measures in groundwater derived from areas of forest in the watershed showed an average of 5 umol/L. Stream discharge and nutrient flux measurements indicated the quality of Greens Creek was impacted by surrounding land use as dissolved inorganic nitrogen increased during its passage through agricultural dominated regions. Creek dissolved inorganic nitrogen showed increases during passage through the watershed up to 5 times greater than background levels over the extent of the creek.

Preliminary measures of nitrate and chlorophyll collected in the tidal creek and adjacent lagoon areas are indicative of the dynamic nature of the groundwater flow of nutrients to the coastal lagoons, and impacts of these nutrients on water quality. Nitrate was high near the terrestrial confluence and decreased readily as one moves away from this influence, and as the creek waters are further diluted with tidal seawater. Chlorophyll levels ranged from 80-100 ug/L in March 1994, during low tide (time of greatest impact from groundwater), in contrast to only 40 ug/L at high tide. Chlorophyll levels decreased drastically with distance from land, further emphasizing the potential impact of terrestrial nitrogen. These data demonstrate the impact of groundwater on the lagoonal system, when it dominates as a nitrogen source during low tide, and further indicate the dilution capacity of the estuary for nitrogen from terrestrial sources as the tide flushes in, as well as when samples are taken further seaward in the estuary. The seasonal influence of terrestrial sources was noted when comparing March (110 ug/L) and May (5 ug/L) data collection results in which chlorophyll levels fell over time. The March sampling was conducted just after agricultural fertilization and a heavy rain event unlike the May sampling which was not associated with any particular agricultural activity.

Conclusion

The results of this initial research suggest that Greens Creek represents a constant but widely variable nitrogen source to the seaside lagoon system and serves as a good site for more detailed evaluation. The construction of a geographically explicit data base of the hydrological and geological framework from the results of this research program, is providing a foundation for nutrient management studies that assist in understanding the buffering capacities within this watershed and provide insight needed to develop more effective cultural practices to reduce nitrate loading and associated impacts on water quality of the seaside ecosystem. Identifying a contaminant source, such as nitrogen, its release history, and the evolution of its transport through ground and surface water, is a mandatory first step toward preventing additional contamination, enacting remedial activities where possible,

designing alternative management practices for ultimate implementation, and demonstrating economically viable cropping procedures for farms within a watershed, such as the one we are studying on Virginia's Eastern Shore. The eventual demonstration of sustainable agricultural techniques by this project will also allow for expansion of effective agricultural contaminant management practices on a broader scale, regionally, nationally, and internationally.

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Farm*A*Syst and Home*A*Syst: Tools for Addressing Watershed Pollution Prevention Needs

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State and local programs are overlooking a significant opportunity to start pollution prevention programs that protect watersheds and source water. Rural residents increasingly recognize the impact of pollution on their lives and are ready to take voluntary action. Generally watershed projects are selected to tackle the worst cases first. Instead of working with motivated volunteers, they contend with bad actors. This intervention is crisis management that focuses on cleanups and not prevention.

Mounting a successful watershed project faces many obstacles. There must be some mechanism to coordinate government agencies that have responsibility for managing rural pollution. This mechanism should also incorporate private sector initiatives. On the front lines, farmers and rural residents need comprehensive and practical assistance that identifies pollution risks and results in voluntary action.

The Farm Assessment System (Farm*A*Syst) and Home Assessment System (Home*A*Syst) Programs responds to each of these concerns. These programs provide unique pollution risk assessment tools and a

flexible framework that has successfully built interagency and private sector partnerships. Easy-to-use assessment worksheets identify pollution risks from a wide range of farm, ranch and home structures and management practices. Fact sheets and technical referrals guide rural residents toward responsible actions to prevent pollution.

In August 1991, the Cooperative State Research, Education and Extension Service (CSREES), Natural Resources Conservation Service (NRCS) and the Environmental Protection Agency (EPA) jointly funded the National Farmstead Assessment Program Coordination Office. The original goal was to create a focused, systematic interagency program to enable farmers and rural residents to identify and reduce drinking water and groundwater contamination from agricultural and household nonpoint and point sources of pollution on their properties. The program has grown significantly because it is meeting the needs of public officials, the private sector and landowners. The program's name has changed to Farm*A*Syst/Home*A*Syst to reflect its growth, but the basic goals remain the same: to link agencies to better serve farmers and ranchers, to provide information that can be applied by landowners to identify pollution risks on their property, to point landowners toward actions that will reduce risks, to facilitate local support to encourages voluntarily action. Through public and private partnerships, these programs are establishing the broad-based commitment necessary for effective voluntary rural pollution prevention.

Growth of the Program

The Farm*A*Syst/Home*A*Syst program and its flexible pollution risk assessments are being well-received. This positive reception has resulted in expansion to include surface water pollution risk assessment, pilot testing as a model of whole farm conservation planning and adaption for use in home environmental assessments (Home*A*Syst). In Ontario, Canada, the program has been expanded into a comprehensive Environmental Farm Planning System. These risk assessments now cover an extensive range:

- Farmstead Assessments
- Water Well
- Pesticide Storage
- Fertilizer Storage
- Petroleum Storage
- Hazardous Waste
- Wastewater
- Livestock Waste Storage
- Poultry Waste Management
- Livestock Yards
- Silage Storage
- Milking Center Wastes
- Site Characteristics
- Cropland Assessments

- Nutrient Management
- Pest Management
- Irrigation Wellhead
- Irrigation Water
- Livestock Waste Application
- In development:
- Pastureland/Rangeland
- Woodlands
- Wetlands
- Home Assessments
- Water Well
- Wastewater
- Liquid Fuels
- Hazardous Waste
- Indoor Air Quality
- Lead
- Solid Waste
- Yard and Garden
- Storm Water
- Energy Conservation
- Site Characteristics

To assess Farm*A*Syst and Home*A*Syst progress, the national office surveys state Farm*A*Syst coordinators each year to determine the status of program development, extent of integration into other programs, sources of funding, types of new materials developed, extent of staff training provided, number of risk assessment conducted, and results of pilot implementation project evaluations. From these surveys, the national office has documented progress in accomplishing the overall goal.

Since 1991, more than 22,000 Farm*A*Syst/Home*A*Syst assessments have been conducted. More than 10,000 assessments were conducted during 1995. Early results from cost/benefits analysis are documenting that the program is returning 3-9 dollars of benefits for every program dollar invested. Participants have voluntarily invested over $15,000,000 to reduce pollution risks on their property. Program evaluations document that participants consistently rank Farm*A*Syst as useful or extremely useful, and would recommend the program to their neighbors. Nearly all participants take at least one action to reduce a pollution risk they have identified. By creating a presence on the Internet, the program is reaching more people. This year the program has received a Renew America Award for Environmental Sustainability in category of pollution prevention.

Evaluation results indicate that:

- 50 states have identified Farm*A*Syst and/or Home*A*Syst program coordinators.

- 27 states have completed development of assessment materials.
- 17 states are in the process of assessment material development.
- 3 states indicate they intend to develop assessment materials.
- 12 states have developed Home*A*Syst programs.
- 27 states have immediate plans to use National Home*A*Syst materials.

Continued Impacts

Farm*A*Syst/Home*A*Syst evaluations document that farm assessments result in immediate actions to prevent pollution and increase knowledge of factors that influence pollution risks. This results in future decisions that reduce pollution risks. The most common high risks identified in farm assessments are petroleum handling and storage; pesticide handling and storage; household wastewater disposal; and well design and management. Table 1 identifies the percent of participants who identify high risks in these areas and the range of costs avoided because of voluntary pollution prevention actions taken. When results of farm assessment cost-benefits studies are applied to the total national program, it is estimated that participants have voluntarily invested more than $15,000,000 to prevent pollution.

Table 1. Cost-Benefits

	% of sites with high risks	Estimated cost if pollution occurs	Typical remediation costs
Petroleum	26 - 63%	$1000 - 100,000	$70,000
Pesticides	17 - 62%	$1000 - 100,000	$70,000
Household Wastewater	17 - 37%	$1000 - 15,000	$10,000
Wells	15 - 35%	$1000 - 20,000	$12,000

The challenge that remains is to find mechanisms to build upon this successful partnership framework to increase pollution prevention within watershed projects.

Pollution Prevention in Watersheds

The flexibility of Farm*A*Syst and Home*A*Syst is illustrated by the extent to which they have been integrated into other programs. Farm*A*Syst and/or Home*A*Syst have been incorporated into watershed projects in twenty-eight states. Table 2 illustrates the number and type of watershed activities

where coordination has occurred.

New York and Minnesota have or are in the process of expanding the Farm*A*Syst framework into a whole farm assessment system. The expanded assessment systems will be used in watershed protection initiatives. In New York, Responsible Environmental Agricultural Planning (REAP) for use in efforts to prevent pollution in watersheds that supply drinking water for the cities of New York and Syracuse. In Minnesota, the Whitewater watershed is a pilot site for the Natural Resources Conservation Service (NRCS) whole farm conservation planning initiative. Both of these programs have been designed to provide farmers with "one step shopping" to develop and implement environmental farm plans. They are intended to be :

Table 2. Number of watersheds using Farm*A*Syst/Home*A*Syst.

Type of Watershed	Farm*A*Syst	Home*A*Syst
USDA Hydologic Units	20	8
USDA Demonstration Projects	9	1
State Watershed Projects	15	23
Community Wellhead or Source Water Protection	17	15

- voluntary.
- farm specific.
- locally administered.
- focused on economically realistic actions.

The Minnesota Whitewater Watershed is pilot testing whole farm risk assessment materials using a promising advance in assessment technology, the Farm*A*Syst Computer Decision Support System (DSS), a computerized version of the assessment worksheets. For this project an expanded version of the DSS is being developed. Field use of DSS shows that computerized delivery shortens and simplifies the assessment process. The software automatically calculates risk rankings for each worksheet and enhances access to fact sheets through on-line help. DSS is programmed to display all pollution risks for the entire property on one screen and to identify actions that respond to those risks. Joe Fitzgerald of the Soil and Water Conservation District in Stearns County, Minnesota says, "The printouts help develop action plans that are effective and easy to implement." With over three years experience using Farm*A*Syst, Fitzgerald indicates that "farmers really appreciate short, precise answers to any problems they have...The farmers were more willing to get busy and address these needs, rather than having to read a long document they don't have time for." He sees measurable difference with DSS, if "we had this system three or four years ago, we'd probably have more than tripled the number of farmsteads protected." Cooperators are comfortable with computer-assisted delivers, saying it is "quick and easy to

understand" and can be "done right on the farm."

DSS simplifies the compilation of data without compromising confidentiality. Keeping data confidential increases the willingness of farmers to participate. Having information on the frequency of high risks identified allows for targeting educational and technical assistance support to the most important risk areas first. Making constructive use of data to refine a voluntary program also boosts participant confidence because they can see the benefits of their participation.

Communities are increasingly showing interest in incorporating Farm*A*Syst and Home*A*Syst programs into their source water protection efforts. Over the past year, 11 states have integrated Farm*A*Syst and Home*A*Syst into source water protection projects. Farm*A*Syst has been integrated into seventeen and Home*A*Syst into fifteen. In general, the increased interest in using Farm*A*Syst and Home*A*Syst in source water protection is linked to recognition that effective programs depend on: accurate identification of structures and management practices that present pollution risks; identification of acceptable actions that reduce risks and prevent pollution and development of support systems that aid individuals in taking voluntary actions that result in source water protection.

Farm*A*Syst and Home*A*Syst programs have the capacity to identify pollution risks and actions needed to prevent pollution. Collective use of these tools within a source water protection area will:

- Identify the extent of pollution risks within a source water protection area.
- Identify the types of actions needed to prevent pollution.
- Increase home and farm owners' and managers' understanding of how their management practices and structures influence pollution risks.
- Increase home and farm owners' and managers' understanding of voluntary actions they can take to prevent pollution.
- Empower community leaders to develop support systems that will encourage and assist home and farm managers in taking voluntary actions that provide source water protection.

Budget limitations will likely require most community efforts to be based on voluntary participation to identify pollution risks and to implement actions to prevent pollution. The delivery approaches that have been used with Farm*A*Syst and Home*A*Syst are ideally suited to meet those needs.

Conclusion

Pollution prevention is recognized as the most cost-effective approach to protecting water quality. Farm*A*Syst/Home*A*Syst provides a mechanism for identifying pollution risks and motivating

voluntary actions to prevent pollution. It provides states with an effective, voluntary system to promote pollution prevention on farms, ranches and rural residences. It strengthens cooperation and builds partnerships among environmental and agricultural regulators, public officials and farm groups, environmentalists and farmers. It provides citizens with an acceptable approach for identifying and addressing pollution risks on their property. These are comprehensive, voluntary pollution prevention programs that can play a major role in watershed management efforts and source water protection projects. Development of effective assessment tools requires interagency and private sector cooperation that can result in coordinated program delivery. Landowner concerns about confidentiality and liability must be addressed to increase voluntary participation. Assessment data can be aggregated to show general characteristics of the watershed and pinpoint problems in the watershed that other sources of information cannot identify.

The national expansion of the Farm*A*Syst and Home*A*Syst programs has documented that this approach can work. Building interagency and private sector cooperation strengthens the overall program, but sometimes requires a major effort. In the end we all have the same objective, namely helping citizens take voluntary actions that prevent pollution. Focusing on the needs and concerns of citizens will help overcome barriers to interagency and private sector cooperation. Where we accomplish this, we all win.

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The Impact of Uncertainty on Risk Assessment with the AGNPS Model

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Introduction

This research developed a methodology for studying the impact of input parameter uncertainty on decision making and risk assessment with a nonpoint source pollution model. The methodology was applied to the Agricultural Nonpoint Source Pollution Model (AGNPS) (Young et al., 1994) linked to the GRASS (U.S. Army Corps of Engineers, 1993) geographic information system (GIS). Although the methodology was applied to AGNPS, it was developed to be utilized with any deterministic computer model which is used for decision making between alternative scenarios.

Methods

Many watershed-based models currently used for nonpoint source or diffuse pollution prediction are deterministic. Single values are used for each characteristic which are then processed by these models to make single value predictions about pollution. For example, the deterministic AGNPS model uses single values for characteristics like soil properties, land cover, and slope and predicts single values for the sediment, sediment-bound, and soluble pollutants in a stream exiting a watershed. Often these single value predictions are compared for various best management practices (BMPs) and planning decisions are made from the comparisons. By comparing only single values, however, the amount of risk involved

with making the decision can not be assessed. Yet, the risk assessment can be one of the most important factors in making a decision for watershed pollution prevention.

By including the uncertainty of input parameters through simulation, the amount of risk involved with making an important watershed pollution prevention decision can be better known. All characteristic parameters used in models have uncertainty due to variability found in the real world and data measurement limitations. A certain soil series may have, on average, 20 percent clay, but has an actual range from 10 percent to 30 percent clay. To represent input parameter uncertainty, a uniform distribution was developed based on a percentage of the original input parameter value. These uniform distributions were developed for all input parameters as some set percentage for different scenarios. A Monte Carlo simulation technique selected values from these intervals to use as model input parameters and produced simulations which could be run through the model. The simulations through the model produced a series of output parameter probability distributions which predict the amounts of pollutants exiting a watershed. In order to make decisions based on the output distributions, several different methods were used to determine the overlap or risk between distributions. Two of these methods were developed as part of this research. The risk between distributions determined the impact of input uncertainty on decision making and risk assessment with the model.

Application

For this research, the methodology was applied to the Hazelton Drain subwatershed of the Sycamore Creek watershed in Michigan with the Hydrologic Unit / Water Quality Tool (HU/WQ) (USDA-NRCS, 1994). HU/WQ was developed by the U. S. Department of Agriculture (USDA) Natural Resource Conversation Service (NRCS) to link together nonpoint source pollution models and GIS. For this research, the HU/WQ link between AGNPS and GRASS was used to create eight AGNPS input files. These eight files reflected the conditions on the subwatershed for two different BMPs (original conditions and contouring on three critical fields) for a 5.08 cm (2.00 inch) rainfall on June 1 for four different years. A Monte Carlo simulation technique was used to include input parameter uncertainty into the AGNPS input files. The input parameter uncertainty was varied from 0 percent to 50 percent at 5 percent intervals, using uniform distributions about the original input parameter values.

Several computer programs were created to do the Monte Carlo simulations, run the simulations through AGNPS, and extract output parameter distributions from the AGNPS output files. The output parameter distributions were created for several sediment and water-soluble pollutants. Alternative BMP/Year scenarios for output parameter distributions were compared, using other specially created computer programs. These comparisons were used to determine the amount of overlap or risk which occurred between the output parameter distributions of alternative scenarios.

Results

The results of these comparisons were used to produce graphs (for each output parameter) of input parameter uncertainty versus output parameter risk for different scenario comparisons. For example,

sediment yield output distributions were compared between various BMP/Year scenarios to determine the relationship between input uncertainty, output risk, and relative difference between sediment yield estimates for the different scenarios. The relative difference between sediment yield estimates for the different scenarios can be represented by a number called the R-Value. This R-Value is the ratio between two estimates of an output parameter at 0 percent uncertainty. It represents how much relative difference there is between any two output values. For example, if BMP A produces a sediment yield of 100 Mg/yr. at the watershed outlet and BMP B produces 200 Mg/yr., the R-Value for their comparison would be 0.5.

The data gathered as part of this research also allows one to make predictions of how different R-Values affect the relationship between input uncertainty and output parameter risk (Figure 1). In Figure 1, an R-Value corresponds to some hypothetical comparison between sediment yield distributions which would have that particular R-Value. The research found that the relationship between R-Values, input uncertainty, and output risk differs for sediment-based and soluble or water-based outputs.

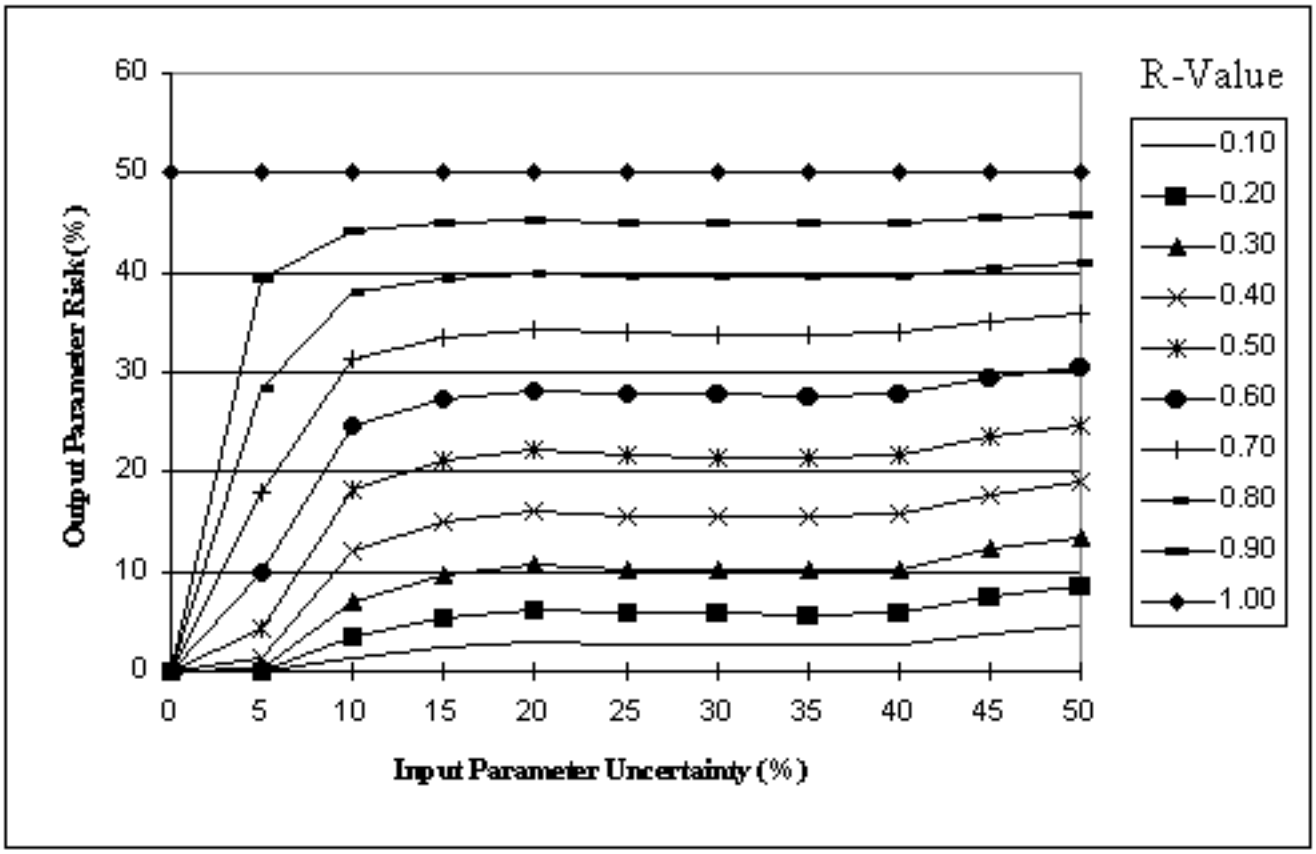

Figure 1. The effect of input uncertainty on risk assessment in sediment yield decisions.

For sediment based output parameters (such as sediment yield in Figure 1), the output parameter risk increases rapidly from 0% to 10% input parameter uncertainty and then levels out. In contrast, soluble or water-based output parameters (such as runoff volume in Figure 2) increase slowly from low input uncertainty levels and continue to increase for the entire range of input parameter uncertainty values. These graphs and their corresponding values can be used to determine the amount of risk associated with a decision between two alternative BMP scenarios, when the input parameter uncertainty is known.

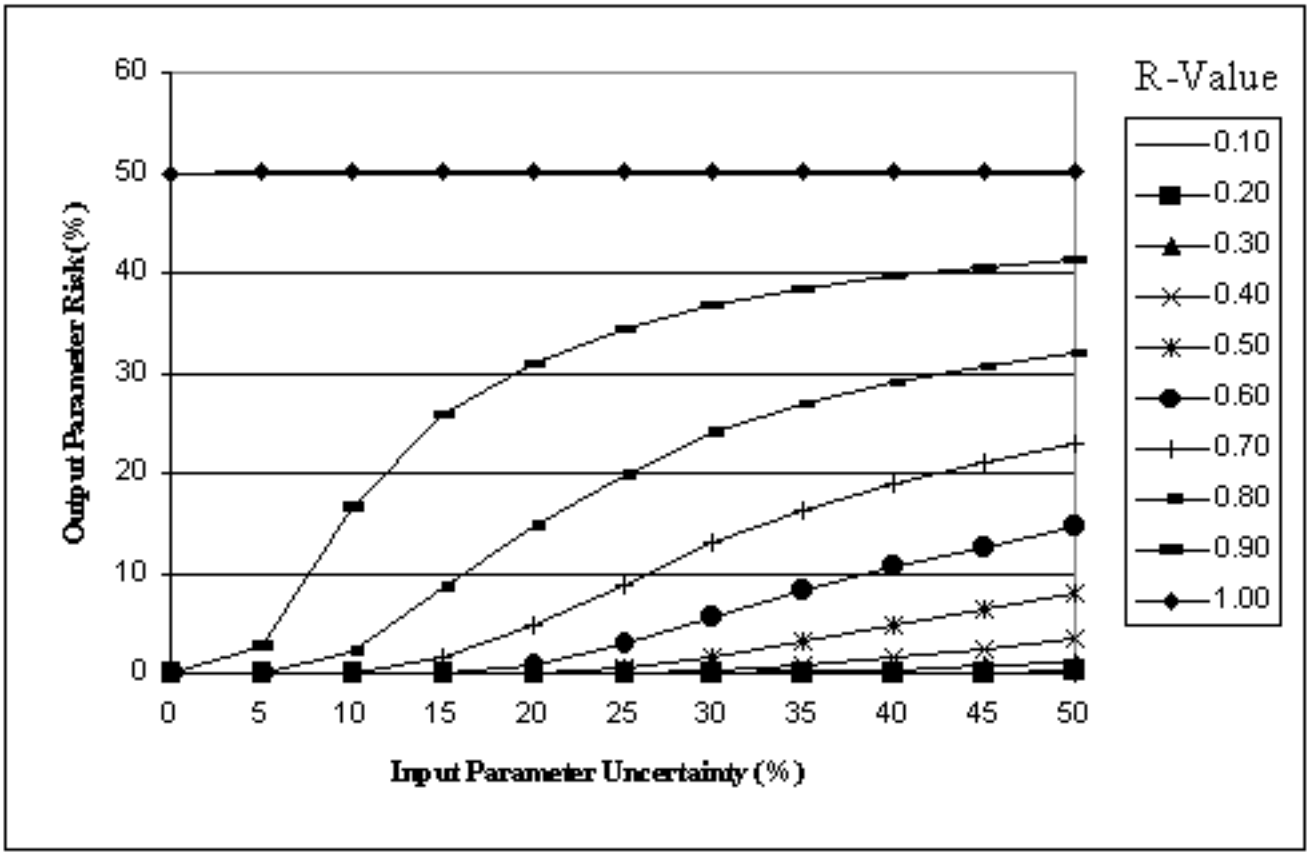

Figure 2. The effect of input uncertainty on risk assessment in runoff volume decisions.

Conclusions

Graphs like Figure 1 and Figure 2 give a decision maker an additional tool in trying to minimize risk. By lowering input uncertainty or R-Values, the risk of choosing between alternative BMPs can be decreased. Input uncertainty is tied to data quality issues. By using better quality model input data from sources such as direct measurements and detailed soil surveys, the input uncertainty lessens. To lower the R-Value, a BMP can be created which does better in reducing the pollutant of concern. In addition, these graphs give some indication of how changes in input uncertainty or R-Values change the risk. For sediment-based outputs (Figure 1), small changes in input uncertainty do not greatly affect the risk, due to the leveling out of the lines. Soluble or water-based outputs (Figure 2), however, show that slight changes in input uncertainty can reduce the decision risk. Both sediment and soluble output have reduced risk for reduced R-Values.

These figures also raise many questions which challenge the traditional understanding of watershed modeling. This research has answered questions like, "What chance is there that one has selected the correct BMP given two alternatives?" By determining the impact of input parameter uncertainty on decision making, future decisions using AGNPS will be better based. Instead of just asking "If" two BMPs are different, the decision maker will also ask "How much different are two BMPs?" As the economic aspects of pollution become much more prominent in decision making, the risk of decisions will become a more essential part of environmental decision making. This will allow future decisions

made with models like AGNPS to take advantage of model capabilities, while also considering the limitations that modeling poses.

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Acronyms

AGNPS Agricultural Nonpoint Source Pollution Model

BMP Best Management Practice

GIS Geographic Information System

GRASS Geographic Resources Analysis Support System

HU/WQ Hydrologic Unit / Water Quality Tool

NRCS Natural Resource Conversation Service

USDA U.S. Department of Agriculture

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Modification of the WERF Methodology for Aquatic Ecological Risk Assessment for Assessing Watershed-Scale Aquatic Risks*

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Introduction

Ecological risk assessment is a process that estimates the likelihood and magnitude of adverse ecological effects from exposure to environmental stresses. It differs from other types of ecological assessments in that it should be quantitative and probabilistic. When properly used, ecological risk assessment can be used to evaluate the ecological and economic costs and benefits of environmental remediation alternatives, such as hazardous waste site cleanup and wastewater treatment. With such use, resources can be allocated to environmental improvement in a more cost and ecologically-effective manner. Consequently, ecological risk assessment is becoming a basic paradigm for environmental decision making. This is reflected in the reorganization of the U.S. Environmental Protection Agency within a ecological risk assessment framework, and the proposed re-authorization of several environmental laws (Clean Water Act, Superfund) to make them more risk based.

However, until very recently, most ecological risk assessments suffered from several deficiencies. First, most were not quantitative and probabilistic. Instead, they were qualitative and deterministic. Virtually all risk assessments were done using the quotient method and the risk characterizations were generally qualitative. Second, most ecological risk assessments only assessed the risks of toxic chemicals and they failed to assess the risks of other non-chemical types of stressors that may have been present concurrently with toxic chemicals. And third, most stressors were evaluated one-at-a-time.

In the past, these deficiencies were not important, because of the large extent of water quality problems caused by toxic chemicals in effluents present in many surface waters. But, because of the successful implementation of the Clean Water Act, most point source discharges of toxic chemicals have been treated or eliminated so that at present few surface waters now have acute or chronic toxicity caused solely by point source discharges. As a result of these improvements, water quality has greatly improved in many previously degraded waters, and with these improvements the ecological integrity of many waters also has greatly improved. Many of the Nation's waters are now "fishable and swimmable". Still, many waters are not attaining their full ecological potential. However, most of the remaining ecological problems are not caused by toxic chemicals, but by other sources of ecological degradation, such as habitat degradation, sedimentation, eutrophication, channelization, urbanization, etc. What is now needed to gain further improvements in the ecological integrity of the Nation's waters are ecological risk assessment methods which can evaluate and quantify the risks of multiple stressors on a watershed scale. With this knowledge, efforts to improve ecological integrity can focus on the most important limiting factors.

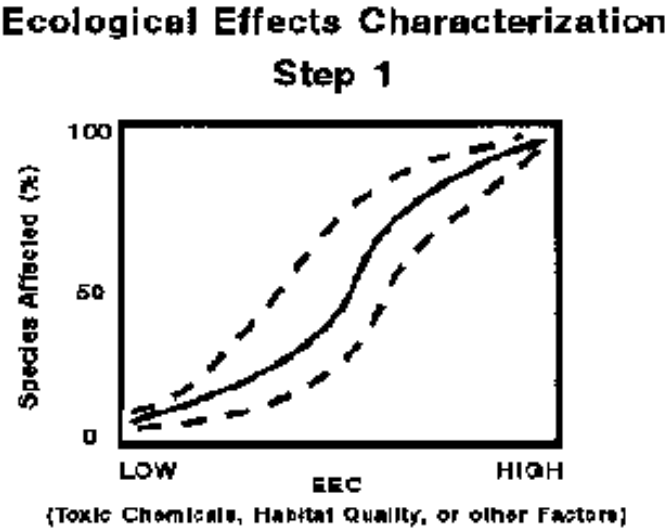
Materials and Methods

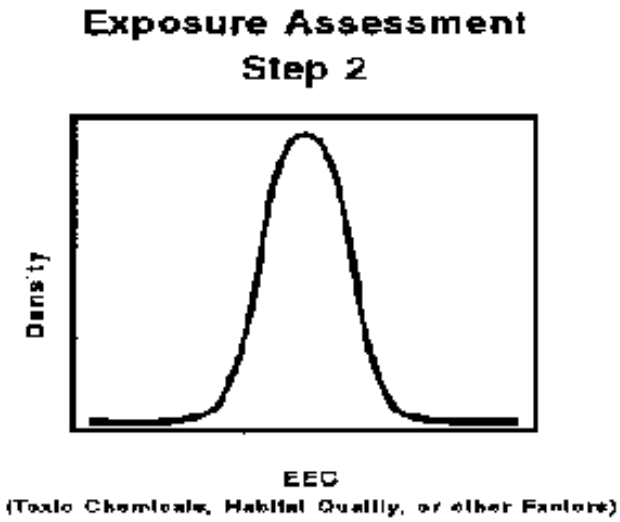
The WERF Methodology for Aquatic Ecological Risk Assessment (Parkhurst et al., 1995), which has been endorsed by the U.S. Environmental Protection Agency, is used to address these issues. The WERF methodology provides quantitative probabIlistic risk assessments for chemicals, which can be applied on a watershed scale. However, chemical toxicity is only one of many stressors that potentially may be affecting aquatic ecosystems within watersheds. Other important watershed-scale aquatic stressors include physical stressors, such as suspended sediments and high water temperatures, hydrologic stressors such as very high and low stream flows, low dissolved oxygen concentrations, and physical habitat degradation. Using the WERF Methodology, we can quantify the risks of habitat degradation and non-toxic chemicals as environmental stressors and compare these risks with the risks from toxic chemicals. The method uses habitat models to estimate the effects of habitat quality on biodiversity. This information is then compared to the risks from chemical toxicity derived from the WERF methodology, which are also assess risks of toxic chemicals to biodiversity. The results compare the relative risks of chemical toxicity with the risks of other types of stressors, so that factors most limiting to a species abundance can be identified. With this information, the types of ecological restoration (e.g. improvements in wastewater treatment, non-point source pollutant reductions, and/or physical habitat improvement) that will provide the greatest aquatic ecological benefit are identified and available resources then can be allocated so as to provide the greatest ecological benefit to the watershed.

The methodology has three tiers: (1) screening-level risk assessment, (2) quantitative risk assessments, and (3) risk refinement and evaluation. Each tier includes six steps, as follows:

1. Stressor identification. Identify sources of stressors of potential concern, such as chemicals (e.g., single or multiple, point or nonpoint, continuous or intermittent) or habitat limitations (e.g., channel modifications, flows, solids, and temperature) that affect the system of concern.

2. Exposure assessment. Estimate the level of exposure of the aquatic community to chemical and/or physical habitat stressors. Expected exposure conditions (EECs) for stressors of potential concern can be estimated using existing data, models, and new data. As an example, chemical EECs can be represented by mean or median concentrations from historical data to estimate chronic risk levels and as 95th percentile concentration for acute risks. Physical habitat EECs can be characterized by the mean of standard habitat indices, which address a wide range of factors including the condition of substrate, channel configuration, pools, banks, riffles, and vegetative cover. In Tiers 2 and 3, probability density distributions of EECs and habitat quality are developed (Figure 1).





Step 3 $E(\text{Risk}) = \int^{\infty} E(R/EEC)\, f(EEC)\, d(EEC)$

$= \int_{0}^{\infty} \text{Logistic Model] [EEC Distribution]}\, dEEC$

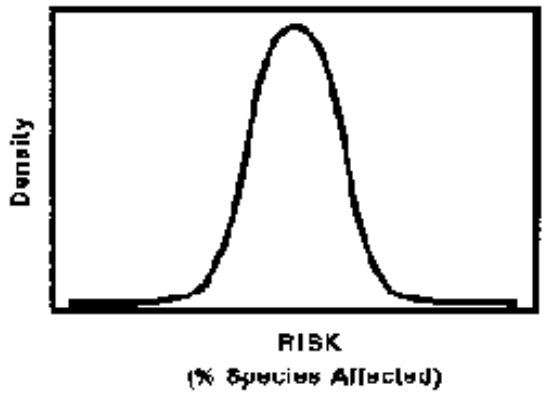


Figure 1. Tier 2 ecological effects characterization, exposure assessment, and characterization for a single stressor.

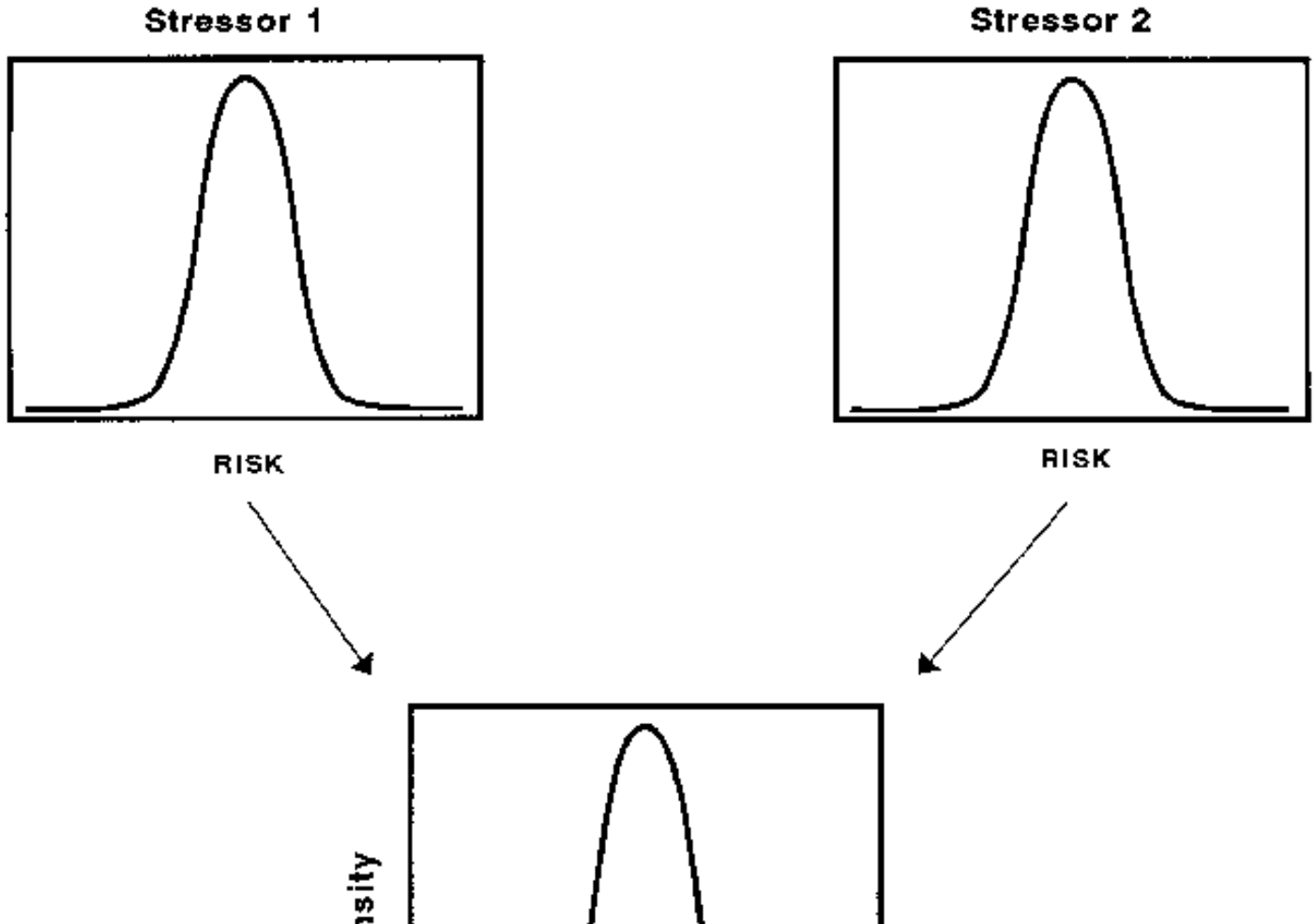
Figure 1. Tier 2 ecological effects characterization, exposure assessment, and characterization for a single stressor.

3. Ecological receptor characterization. Identify aquatic biota that are potentially at risk in the specific location being evaluated. The assessment endpoints can be individual species of special concern, such as game fish, or the community level endpoint, biodiversity.

4. Ecological effects characterization. Determine ecological risk criteria (ERCs), or levels of chemical contaminants and/or physical conditions that could adversely affect the aquatic biota identified in Step 3 above. In Tier 1, for chemical constituents, ERCs can be defined by acute or chronic water quality criteria, or by some other value that defines community level effects. Tier 1 criteria to assess the impacts of physical limitations are habitat suitability indices for individual species, and habitat quality indices for the community. In Tier 2 and 3, models are developed that quantify the relationships between the magnitude of the stressor (EEC) and the percent of species affected (Figure 1).

5. Risk characterization. Tier 1 uses the quotient method for risk characterization. The output from Tier 1 is a list of stressors of potential concern. In Tier 2, risks are quantified by integrating the probability density distributions of the stressors (chemicals and habitat) with the probability density distribution for the modeled effects of the stressor (toxicity, habitat quality, Figure 1). Stressors are assumed to be additive in their effects on an individual species or the number of species; therefore, the cumulative effects of multiple stressors can be estimated by integrating the risks of all stressors (Figure 2).

$$\int_{0}^{\text{All Stressors}} \int_{1}^{\infty} E(R/EEC)\, f(EEC)\, dEEC$$



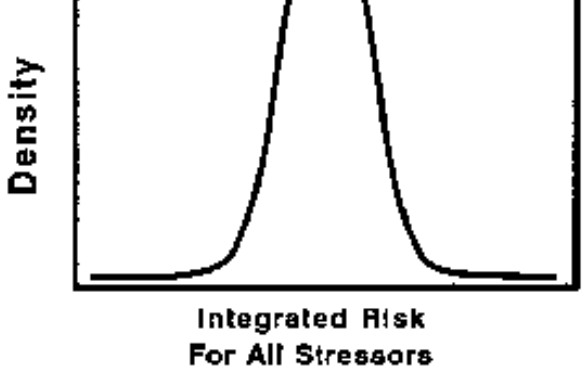


Figure 2. Tier 2 Risk Characterization for Multiple Stressors.

6. Risk management. Evaluate the potential ecological benefits of mitigating chemical and/or physical limitations by looking at reductions in the total community risk, by removing a given limiting factor from the analysis and re-evaluating the overall risk. The results of this analysis can help to determine the relative value of remediating various factors. For example, it may not be worthwhile to reduce metal concentrations, if the reduction in total risk is relatively minor due to overwhelming risk posed by habitat and chloride.

Discussion

The results of the risk characterization provide a tool for evaluating in a quantitative and probabilistic manner the risks of multiple stressors, including both toxic chemicals and physical habitat. It can be used to determine the most cost-effective means for improving aquatic ecological integrity on a watershed scale. Watershed scale ecological risk assessment is completely consistent with the statewide watershed management approach that has been recently developed and implemented by several states. The risk characterization supports the priority setting, targeting, and development of management strategy elements of the statewide watershed approach. The statewide watershed management approach creates enhanced opportunities for the use of ecological risk assessment. The approach uses geographically defined management units and requires explicit priority setting procedures. With more states developing this approach, there is both an increasing need and opportunity for watershed scale ecological risk assessments.

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Application of Aquatic Ecological Risk Methodology to Support Site-Specific Water Quality-Based Permitting

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Brown and Caldwell

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The objective of the Clean Water Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." To date, efforts to protect aquatic life have focused on individual chemical constituents, using well-established methodologies to compare instream concentrations to criteria. However, there has been recognition that physical and biological integrity are at least as important as chemical conditions and often more important.

Aquatic ecological risk assessment is one tool that can be applied to effectively integrate impacts from multiple chemical and physical parameters on biological systems and to evaluate the relative importance of specific factors. This approach can be used to evaluate the probability and magnitude of adverse aquatic ecological effects that could result from exposure to one or more toxic chemicals, as well as other stressors, such as poor physical habitat. The results of aquatic ecological risk analysis can be applied to identify the relative importance of various stressors on aquatic life, the total risk from multiple stressors, and ecological benefits of mitigating identified stressors.

Across the country, there has also been a move to refine water quality-based permitting approaches to provide appropriate levels of protection without being overly conservative. In a recent vision statement, the U.S. EPA stated a need to "integrate new science into a basin management approach that enables flexible, sensible decisions" and to "avoid a program that results in costly requirements that have little or no environmental benefit" (U.S. EPA, 1995). Ecological risk assessment is a tool that can be applied to identify limiting factors in an aquatic system and to help ensure that resources are directed toward providing real environmental benefits by focusing on the most significant limiting factors and not wasting resources on factors that are relatively insignificant.

Aquatic Ecological Risk to Address Multiple Stressors

In considering the overall ecological risk to an aquatic system, a number of factors must be considered, including chemical pollutants from natural, point, and nonpoint sources; and physical limitations resulting from low flow conditions, channel straightening and widening, high suspended solids loadings, and high temperatures. The challenge is to develop a uniform framework in which to compare the relative importance these dissimilar types of limitations.

A quantitative, probabilistic methodology for aquatic ecological risk assessment has been developed for the Water Environment Research Foundation, which has been reviewed and endorsed by the U.S. Environmental Protection Agency (Parkhurst et al., 1996). Although the methodology was developed specifically for application to chemical parameters, it can also be applied to address physical limitations with some modifications, as described below.

The methodology has three tiers: (1) screening-level risk assessment, (2) quantitative risk assessments, and (3) risk refinement and evaluation. Each tier includes six steps, as follows.

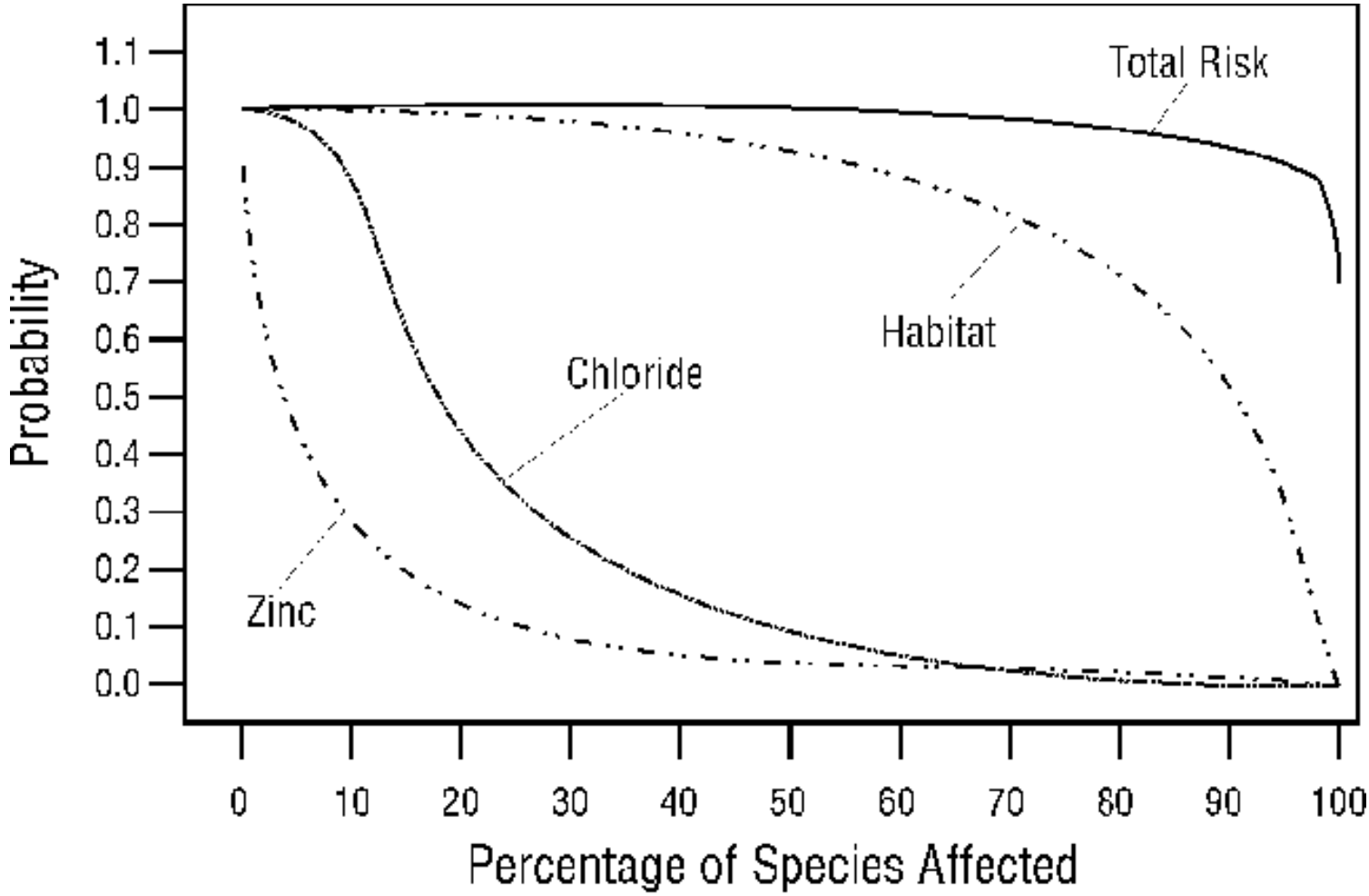
1. Stressor identification. Identify sources of stressors of potential concern, such as chemicals (e.g., single or multiple, point or nonpoint, continuous or intermittent) or habitat limitations (e.g., channel modifications, flows, solids, and temperature) that affect the system of concern.

2. Exposure assessment. Estimate the level of exposure of the aquatic community to chemical and/or physical habitat stressors. Expected exposure conditions (EECs) for stressors of potential concern can be estimated using existing data, models, and new data. As an example, chemical EECs can be represented by mean or median concentrations from historical data to estimate chronic risk levels and as 95th percentile concentration for acute risks. Physical habitat can be characterized by the mean of standard habitat indices, which address a wide range of factors including the condition of substrate, channel configuration, pools, banks, riffles, and vegetative cover.

3. Ecological receptor characterization. Identify aquatic biota that are potentially at risk in the specific location being evaluated. Receptors may include communities or individual species of benthic macroinvertebrates and fish. Biological assessment approaches, including rapid bioassessment protocols (U.S. EPA, 1988) and biological criteria (U.S. EPA, 1994) have more recently focused on communities rather than individual species since community-based approaches provide a more comprehensive ecological evaluation.

4. Ecological effects characterization. Determine ecological risk criteria (ERCs), or levels of chemical contaminants and/or physical conditions that could adversely affect the aquatic biota identified in Step 3 above. In Tier 1, for chemical constituents, ERCs can be defined by acute or chronic water quality criteria, or by some other value that defines community level effects. Tier 1 criteria to assess the impacts of physical limitations are habitat suitability indices for individual species, and habitat quality indices for the community. In Tier 2 and 3, models are developed that quantify the relationships between the magnitude of the stressor and the number of taxa or the abundance of a species.

5. Risk characterization. Tier 1 uses the quotient method for risk characterization. The output from Tier 1 is a list of stressors of potential concern. In Tier 2, risks are quantified by integrating the probability density distributions of the stressor (chemical or habitat) with the probability density distribution for the modeled effects of the stressor (toxicity, habitat quality). Stressors can be assumed to be additive in their effects on an individual species or the community. Figure 1 provides an example of a Tier 2 risk characterization.



6. Risk management. Evaluate the potential ecological benefits of mitigating chemical and/or physical limitations. Determine reductions in the total system risk, by removing a given limiting factor from the analysis and re-evaluating the overall risk. The results of this analysis can help to determine the relative value of mitigating various factors. For instance, it may not be worthwhile to reduce zinc concentrations in the example in Figure 1, if the reduction in total risk is relatively minor due to overwhelming risk posed by habitat and chloride.

Application of Aquatic Ecological Risk in Permitting

Aquatic ecological risk methods can be used to help define the appropriateness of proposed water quality-based NPDES permit limits and to support alternative approaches. A conceptual example is presented below to illustrate how these methods could be applied and incorporated within the water quality standards and permitting processes.

Stressor Identification

As an example, consider a system with the following types of stressors:

- A natural, continuously occurring chemical (e.g., chloride).
- A chemical constituent discharged continuously from a point source (e.g., zinc).
- Long-term physical habitat limitations due to channelization.
- Intermittent habitat limitations due to low flow conditions.

Exposure Assessment and Ecological Effects Characterization

Expected exposure conditions could be calculated as the mean and variance for concentrations for the two continuously occurring chemical constituents, based on data collected during baseflow conditions (a minimum of three measurements at each site, covering the range of seasonal conditions, are recommended). Standard habitat sampling methods would be used to characterize habitat conditions and physical EECs could be calculated as the mean and variance for the habitat quality indices.

Risk Characterization

Risks from the two chemicals and habitat quality are quantified and presented as in Figure 1. In this particular example, on average about 90% of the species are adversely affected by habitat quality, 25% by chloride toxicity, and 5% by zinc toxicity. In addition, 95% confidence limits for these risk estimates can be estimated.

Risk Management

The ecological risk analysis in the above example indicates that two factors dominate the total risk to the aquatic communities_the naturally occurring pollutant and habitat limitations. The natural pollutant is inalterable, but the next most effective means to reduce risk to the aquatic communities is to address the habitat limitations due to channelization and extreme low flow conditions. This could be achieved through channel restoration and establishment of a minimum instream flow. In this example, the chemical constituent discharged from the WWTP also exceeds instream criteria occasionally, but constitutes a relative small portion of the total risk to the aquatic community. The implementation of costly improvements to the WWTP would provide only limited improvements in the aquatic communities.

In the past most ecological risk assessments have focused on toxic chemicals and have ignored the effects of other important stressors to aquatic ecosystems. In addition, most risk assessments have not been quantitative or probabilistic. This example illustrates how the WERF Methodology for Aquatic Ecological Risk Assessment can be used to identify and quantify the risks of all important stressors to aquatic communities in a probabilistic manner and identify the most cost-effective ways to improve the quality of degraded aquatic systems.

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The Use of Risk Analysis in Watershed Planning Activities

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Abstract

A risk analysis approach has been adapted for use in watershed planning activities to assist with risk-based decision-making. This approach consists of two phases: risk assessment and risk management. This watershed-based approach includes an evaluation of major areas of uncertainty. A hypothetical watershed is used to illustrate the application of the approach in a watershed context.

The watershed risk assessment approach follows the current EPA ecological risk assessment paradigm of problem formulation, analysis, and risk characterization. Problem formulation involves identification of watershed resources and receptors, and selection of priority assessment endpoints. During this stage, physical, chemical, and biological watershed-specific stressors are identified. Measurement endpoints (e.g., water quality, criteria, 7Q10 flows) are selected based on the desired level of resource protection.

Analysis identifies exposure pathways and scenarios to assess the levels of human and ecological receptor exposure to various stressors. Analysis for watershed management often consists of evaluation of human and/or ecological exposure to stressors, water quality modelling, and hydrological and hydrodynamic analyses. Risk characterization involves estimating risk to both human health and ecological interests and identifying appropriate decision-making criteria.

Watershed-based risk management helps interpret the level of risk and select the appropriate course of action. In addition to the risk assessment results, the proposed watershed based risk management approach incorporates a variety of social, legal, political, and economic factors.

Definition of Risk in a Watershed Context

Risk can be broadly defined as an estimate, either qualitative or quantitative, of the probability or likelihood of an event taking place. Risk assessment for regulatory decision-making is typically divided into human health risk assessment and ecological risk assessment. Human health risk assessment is concerned with estimating potential adverse effects (e.g., mortality or incidences of cancer) to human populations. Ecological risk assessment has a broader scope and looks to estimate the potential impacts to plant and animal species, the biological communities that they comprise, and the habitats and ecosystems in which they reside.

Watershed risk management is defined as the process used to estimate the probability for adverse effects to watershed resources and receptors as part of an integrated watershed management. Because watershed management involves evaluation of the desires of the watershed's human residents and the needs of the natural environment, watershed risk management incorporates components of both human health and ecological risk assessment.

The move to a balanced assessment is historically analogous to the changing goals of watershed management, which originally arose out of a desire to improve selected water uses such as flood control, elimination of waterborne diseases, or providing hydropower. Watershed management now encompasses environmental concerns such as minimum low flows, prevention of eutrophication, protection of critical habitats, and maintenance of sediment quality.

Application of the Risk Assessment Framework to Watershed Management

The risk assessment approach adapted for watershed management was proposed in Framework for Ecological Risk Assessment (U.S. EPA, 1992) and recently modified in Draft Proposed Guidelines for Ecological Risk Assessment (U.S. EPA, 1995). This approach incorporates several elements of the human health risk assessment paradigm (NAS, 1983). The risk assessment consists of three parts: problem formulation, analysis, and risk characterization. An illustration of the use of risk analysis for decision-making in a simplified, hypothetical watershed is shown in Figure 1.

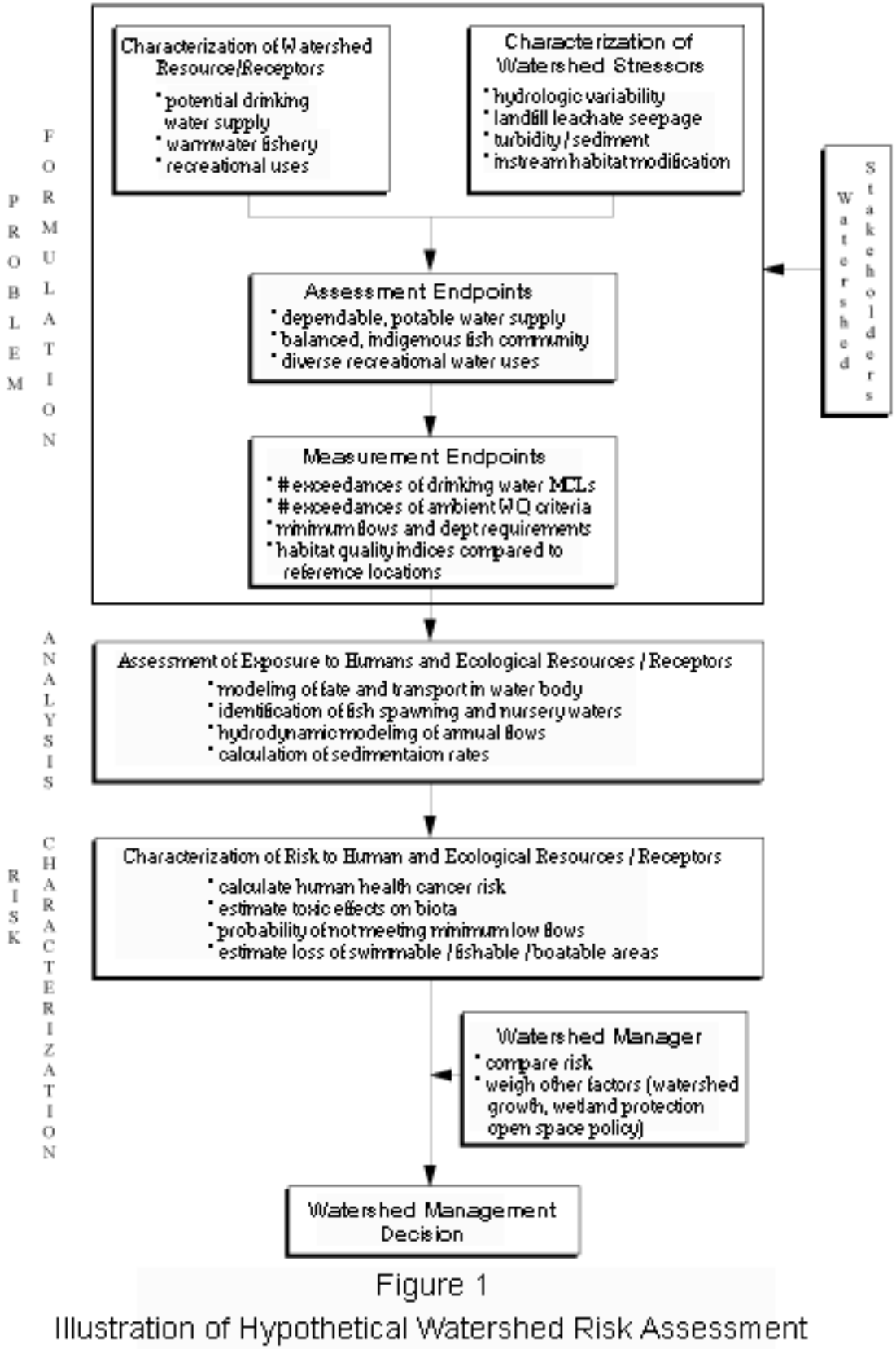

Figure 1. Illustration of Hypothetical Watershed Risk Assessment.

It is important to recognize the difference between risk assessment and risk management. The former is based on scientific methods to provide an objective assessment of the likelihood of risk. The latter is the decision-making result of risk assessment, which weighs the results of risk characterization against competing considerations, such as beneficial effects, socioeconomic factors, competing resources, or

regulatory policy, to arrive at a final watershed management decision. Accordingly, it is incumbent upon the risk assessor to clearly and precisely communicate the nature and scope of potential risks to the watershed manager, who acts as risk manager.

Problem Formulation

The initial planning and scoping process which defines the watershed-based risk assessment scope and objectives is problem formulation. Problem formulation includes the following steps:

- Development of information on and an understanding of general watershed characteristics (land types, hydrology, water quality).
- Identification of human and ecological resources and receptors within the watershed (human population, biota and habitats).
- Selection of assessment endpoints through an initial screening process to select critical or representative resources to be evaluated in the risk assessment study.
- Identification of stressors that might adversely affect watershed resources (physical, chemical, biological).
- Selection of risk assessment measurement endpoints or values that will be used to evaluate potential risks.

After the initial inventory of watershed characteristics, resources, and receptor, selection of the priority water uses to be protected should involve a consensus of the watershed stakeholders. These uses frame the identified assessment endpoints (e.g., maintenance of balanced, indigenous fishery). The stressors of concern in a watershed may include physical (e.g., drought, flooding, water diversion, sedimentation, or alterations in habitat, light, thermal, or energy regimes); chemical (e.g., toxic chemicals, cultural eutrophication, and salinization); and biological (e.g., invasive exotics, pathogens). The impact or risk of the stressors to assessment endpoints are quantified by the measurement endpoints (e.g., number of exceedances of drinking water standards).

Analysis

The objectives of this phase of the risk assessment are to:

- Identify exposure pathways and scenarios.
- Qualitatively or quantitatively assess the levels of exposure and effects on human and ecological receptors from watershed stressors.

Human health and ecological risk assessments have traditionally focused on chemical stressors. On a watershed scale, humans may be exposed to chemical stressors via withdrawal of water for household use; ingestion of contaminated fish, shellfish, or wildlife; exposure to surface water or sediments while swimming or bathing; and a variety of indirect exposure pathways. The exposure assessment for aquatic resources to toxic chemicals involves estimation of chemical concentrations in water and sediments at habitats where ecological receptors are located and may be exposed. In order to assess exposure to terrestrial receptors, chemical concentrations in aquatic organisms that may serve as food for terrestrial predators must also be estimated or determined (e.g., bioaccumulation).

Risk assessment tools can be used to identify watershed-specific chemical exposure pathways and scenarios, and to estimate locations and numbers of receptors, chemical exposure concentrations, chemical doses, and toxicity threshold values. Modeling is frequently conducted to provide a cost-effective means of evaluating human and aquatic exposures to chemical stressors (e.g. WASP5).

A primary physical stressor for human receptors is flooding within a watershed. Assessing this stressor may involve hydrologic and hydraulic modeling, determining flood flows, and delineation of areas of inundation during flooding events. Ecological exposures to and effects from physical stressors may be evaluated through a variety of methods, including various fish and macroinvertebrate bioassessment protocols and instream flow models.

Pathogenic bacteria and viruses are likely to be the most significant biological stressors for human receptors. Primary pathogen exposure pathways include ingestion of drinking water, shellfish, and fish. Quantification of human exposure to and effects from biological stressors may be based on direct measurements or on modelling predictions. The primary biological stressors of concern for ecological receptors are invasive exotic plant and animal species. Field surveys can be used to monitor spatial and temporal trends and to estimate colonization rates of invasive plants and animals.

As part of the analysis, the adverse response of the receptor to the stress must be determined (e.g., dose-response value, LC50, population loss, etc.) and acceptable levels of stress identified. These values are generally derived from the scientific literature or appropriate databases (e.g., HEAST, IRIS, AQUIRE, ECOTOX).

Risk Characterization

The concluding portion of the risk assessment:

- Combines the results of the exposure assessment and predicted effects of stressors on watershed receptors or resources.

- Determines the potential for adverse effects to occur in the watershed receptors or resources.

- Provides an estimate of the uncertainty associated with the predicted effects.

In the context of watershed management, risk characterization can be used to quantify adverse impacts to watershed receptors. Risk characterization of chemical stressors is perhaps the clearest and least ambiguous assessment. Comparison of a chemical-specific media concentration to a regulatory criterion (e.g., drinking water MCL) or federal ambient water quality criteria (AWQC) provides an easily calculable ratio (e.g., hazard quotient or toxicity quotient. This ratio can provide a direct mathematical expression of whether certain water uses or protective regulatory criteria are being met. Alternatively, for non-numerical determinations, quantifiable or describable habitat dimensions, areal representations, or temporal properties can be compared to reference areas, "typical" values, or a pre-determined limit (e.g., critical flow).

The risk assessment process is inherently uncertain. Information is often limited for a great many factors or parameters used in a risk assessment (e.g., extent of chemical contamination, nature of human and wildlife exposures, chemical toxicity). Consequently, practitioners of risk assessment must make assumptions when exact information is lacking. It is therefore important to specify the assumptions and uncertainties inherent in the risk assessment to place the risk estimates in proper perspective. The identification and evaluation of key uncertainty factors or parameters in a risk assessment is referred to as uncertainty analysis.

Uncertainty analysis can be qualitative, involving a discussion about the major areas of uncertainty, the assumptions made to compensate for the uncertainty, and the likely effects on the risk results if alternative assumptions were made. Alternatively, uncertainty analysis can be highly quantitative, involving characterization of the probability distributions for key input variables and propagating parameter uncertainties through the analysis using analytic (e.g., first-order analyses) or numerical methods (e.g., Monte Carlo simulation). It is critical that decision-makers who use risk assessment results understand the extent of the model's limitations and its results.

Risk Management

In addition to the risk assessment, social, legal, engineering, political, and economic factors are considered in the risk management phase of watershed risk analysis. Legal decisions consider the relevant watershed laws being implemented. Practical technologies are often considered in the engineering evaluation. An understanding of costs and economic benefits, as well as local and regional social contexts, is critical to making informed watershed risk management decisions. It is desirable to develop a framework on a watershed-specific basis for eliminating de minimis risks and concentrating on significant risks (Suter, 1993). This allows the watershed manager to identify the watershed stressors which need to be addressed and their relative importance in achieving watershed goals.

Summary

The current risk analysis paradigm can be adapted for purposes of watershed management. It presents a

conceptual model for identifying watershed resources at risk and evaluating the potential impact of watershed management options.

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Developing Cost Effective Geographic Targets for Nitrogen Reductions in the Long Island Sound Watershed

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

Since its inception in 1985, the Long Island Sound Study (LISS) has been characterizing the primary water quality and habitat problems affecting Long Island Sound and implementing management plans to address those problems. LISS, a member of EPA's National Estuary Program (NEP), is a partnership of the Connecticut Department of Environmental Protection (CTDEP), the New York State Department of Environmental Conservation (NYSDEC), and EPA at the policy level, but the formal conference established under NEP draws in state, federal, and local agencies as well as non-government public and private interests.

LISS has emphasized the problem of hypoxia, or low dissolved oxygen, which establishes itself in

bottom waters of more than half of Long Island Sound during the late summer each year. While the natural phenomenon of stratification makes the Sound very susceptible to hypoxia, water quality monitoring and modeling has supported nutrient enrichment as the primary cause of the severe hypoxia experienced today. The model, named the "LIS 3.0" model, was developed by HydroQual, Inc. of Mahwah, NJ, under an EPA-LISS contract. LIS 3.0 demonstrates that under pre-Colonial conditions hypoxia did not occur and that nitrogen enrichment is the key nutrient for management purposes as it limits phytoplankton productivity during peak bloom periods. LIS 3.0 also shows that nitrogen control, if aggressive enough, can raise late summer oxygen to levels that would be protective of most aquatic species that inhabit the Sound.

Nitrogen originates from both natural and anthropogenic sources in the Sound's 16,000 mi2 drainage basin, plus from atmospheric deposition and through the "boundaries" where Long Island Sound connects with the Atlantic Ocean via The Race and New York Harbor via the East River. By far, the dominant human source of nitrogen is municipal sewage treatment plants, but atmospheric deposition and nonpoint sources contribute substantial nitrogen loads that provide other management opportunities.

LISS is implementing a phased approach to reducing nitrogen loadings to the Sound from point and nonpoint sources within the Sound's drainage basin. Phase I, announced in 1990, established a freeze on point and nonpoint nitrogen loadings to the Sound in critical areas. Phase II, announced in 1994, set commitments for low cost actions to begin to reduce the annual load of nitrogen. LISS is now working to identify long-term nitrogen reduction targets for point and nonpoint sources within the drainage basin. LISS is charged with developing a cost-effective approach to ensure implementation is not only technically feasible, but fair and supportable by both government and the public. For this example, only point source contributions are considered, but targeting for nonpoint source management will follow the same pattern of analysis.

Geographic Segmentation

The first step in the process was to divide the Long Island Sound watershed into several smaller units or segments. These segments are more manageable with respect to nitrogen load calculation, monitoring, and planning. Eleven segments or management zones were established based on natural watershed boundaries that drain to Long Island Sound within the states of Connecticut and New York (Figure 1). Some of the management zones in the larger basins of Connecticut were further divided into two to four tiers (Figure 1). This reduced size variation among the zones and also allowed accounting for nitrogen attenuation that naturally occurs during transport downriver from the more distant tiers. As a general assumption, all anthropogenic nitrogen originating in the first tier of Zones 1 through 4, and in all of the remaining zones (5-11) that have only one tier, was delivered to Long Island Sound with 100 percent efficiency. Nitrogen originating in higher tiers was attenuated, the amount depending on estimates empirically derived from monitoring data. Because of attenuation, and the increasing inefficiency of managing more distant sources, nitrogen exported from areas north of Connecticut is not being considered for management at this time.

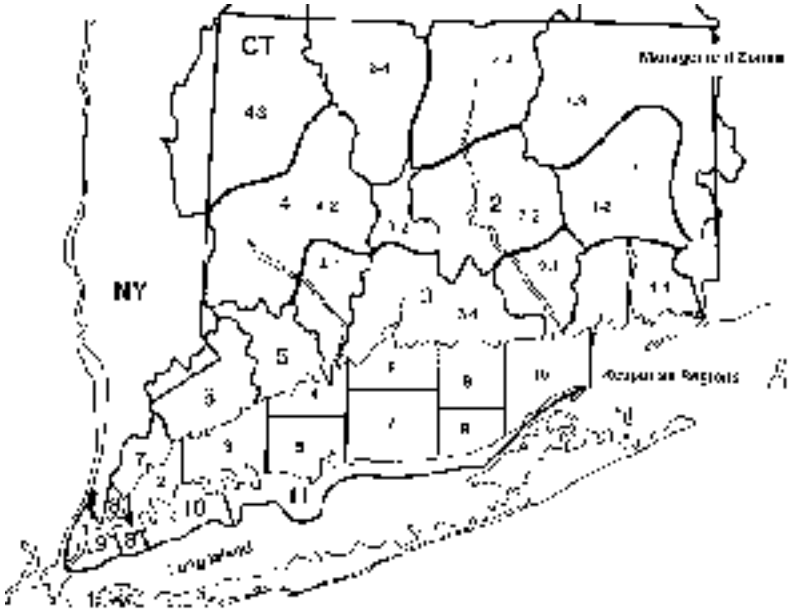

Figure 1. Geographic segments (zones and tier) and response regions for Long Island Sound.

Nitrogen Sources

Point sources dominate the anthropogenic load of nitrogen to Long Island Sound and provide good material for a descriptive analysis. Publicly-owned sewage treatment plants are the predominant point source although two industries in Connecticut also contribute substantial portions of nitrogen. The nitrogen load is apportioned among the 19 zones and tiers according to development patterns, which concentrate much of the load near western Long Island Sound and central Connecticut (Table 1). However, some of the nitrogen load originating in central Connecticut (e.g., Zone 2, Tiers 2 and 3; and Zone 3, Tier 2) attenuates during transport to the Sound, as discussed earlier (Table 1). That loss must be accounted when relative benefits and costs associated with management are calculated to realize the true benefit affecting the Sound.

Oxygen Response in the Sound

The HydroQual, Inc. LIS 3.0 model was used to determine the dissolved oxygen response to nitrogen removal from each of the management zones. Because the LIS 3.0 model is a sophisticated, three-dimensional model that is calibrated to actual conditions in the Sound, the dissolved oxygen response varies depending upon where in the Sound the response is being predicted and from which management zone the nitrogen is coming from. These relationships must be considered because, like the attenuation factor for more distant sources of nitrogen, there are higher cost efficiencies when managing sources of nitrogen that result in a larger dissolved oxygen improvement. To simplify the analysis, the Sound was divided into ten response regions (Figure 1) within which a single dissolved oxygen response, representative of each respective response region, was used to evaluate the response to nitrogen management scenarios being tested. A unit response matrix was prepared by HydroQual to identify the relative response of dissolved oxygen in each response region based on an equal amount of nitrogen (in

this case 10,000 lbs/day) removed from each of the 11 management zones. Oxygen response varies depending on both the geographic source of nitrogen and the response region in the Sound (Figure 2).

The Cost of Management

The final ingredient in establishing cost-effective geographic targeting of nitrogen management is the cost/benefit evaluation of each management activity. Each point source was evaluated by CTDEP, NYSDEC, and New York City Department of Environmental Protection (NYCDEP) staff to determine how much it would cost to remove nitrogen at two or three general reduction levels. The costs and reductions were compiled by geographic segment and the dissolved oxygen benefit paired with each segment's total cost after accounting for both attenuation for the more distant tiers and the dissolved oxygen response depicted in Figure 2. This cost/dissolved oxygen benefit relationship was graphed to develop a cost curve to help assist LISS identify the point at which additional nitrogen reductions result in diminished dissolved oxygen improvements relative to increased cost (Figure 3).

Target Setting

Striking a balance between cost and technical feasibility shown in the cost curve and resource protection is a difficult and laborious process. Many other factors will come into play before that decision is negotiated among all the stakeholders and regulators of Long Island Sound. The ultimate management goal being addressed is to achieve dissolved oxygen concentrations protective of most of the resident aquatic life. LISS will use the information from the cost curves in combination with other factors to help identify a Sound-wide nitrogen reduction target for point and nonpoint sources that maximizes progress toward this goal. Management of more distant sources, including those contributing to atmospheric deposition, may be necessary to fully meet the dissolved oxygen goal.

While it is desirable to minimize the overall costs to society for achieving environmental improvements, a fair and equitable means of distributing responsibility is of paramount concern. This is especially true now that primary financing of improvements in sewage treatment has been shifted from federal to state and local levels. LISS hopes to achieve geographic and source equity by distributing the necessary nitrogen reductions among the management zones based on their relative contribution to the problem. Within each management zone, flexibility to distribute management actions among point and nonpoint sources will be allowed as long as the overall reduction goals are met.

To encourage innovation and spur market efficiencies, LISS is investigating effluent trading as a mechanism for state administration of the program. As each segment bargains for the least expensive way to meet its assigned target, actual reductions achieved by the most cost efficient sources would go up, while the expensive geographic areas would contribute less nitrogen reduction, instead providing funds to the efficient areas for additional controls. For example, a cost-inefficient point source may arrange for (fund) another point source to undertake greater than required control in lieu of upgrading its own treatment. To ensure that water quality improvements are not compromised, "currency" rates for trades among different geographic segments will be set based on the LIS 3.0 model.

Conclusion

LISS will continue to evaluate the cost curves, for point sources and for nonpoint sources of nitrogen to help identify cost-effective levels of management. Other factors, such as the significance of dissolved oxygen impairments on habitat quality, equity of management responsibility, and availability of financing, will be considered in establishing nitrogen reduction targets for each of eleven watershed management zones. It is hoped that the provisions of sound economic analysis and free-market trading will help assuage concerns over the fairness of the system, while still accomplishing resource goals needed to correct hypoxia in Long Island

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Models of Nonpoint Source Water Quality for Watershed Assessment and Management

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Watershed models are being used extensively as tools for assessment and evaluation of management activities for resource and environmental issues throughout the United States and abroad. These models typically include components to deal with both point and nonpoint contamination sources, and the nonpoint source assessment must consider all potential sources, including both urban and rural (i.e. non-urban) land areas and associated activities. This paper briefly summarizes a major nonpoint source model review effort published by the U.S. EPA in 1991 that focussed on nonpoint source assessment procedures and modeling techniques for both urban and non-urban land areas (Donigian and Huber, 1991). That report provides detailed reviews of specific methodologies and models, along with overview discussions and model comparison tables. Simple procedures, such as regression and loading function approaches are also described in the report, along with complex models such as SWMM, HSPF, STORM, CREAMS/GLEAMS, SWRRB, AGNPS, and others. Brief case studies of modeling efforts are summarized with emphasis on the use of nonpoint and comprehensive watershed models for watershed management activities. In this brief paper, we focus on the comparative evaluation of the major simulation models used for both urban and non-urban nonpoint source and water quality assessments.

Overview of Available Nonpoint Source Modeling Options

Several modeling options exist for simulation of quality in urban storm and combined sewer systems. These have been reviewed in the literature and range from simple to involved, although some simple methods, e.g., the EPA statistical methods, can incorporate quite sophisticated concepts. The principal methods available to the contemporary engineer, in a rough order of complexity, include: constant concentration, spreadsheet, statistical, rating curve or regression, and buildup/washoff. A comprehensive description of each of these five methods is provided in Donigian and Huber (1991) and Donigian et al. (1995). Although some of these options are used as stand-alone techniques, they are also included as alternatives in the available simulation models.

Similarly, modeling nonpoint source pollutants from non-urban areas ranges from simple annual 'loading functions' to detailed process simulation models. The key issue in estimating nonpoint pollution loads from a watershed is the type and extent of human activities occurring on the land. The same hydrologic, physical, and chemical/biological processes that determine nonpoint pollutant loads occur on all land surfaces (and in the soil profile) whether it is urban, forest, agricultural cropland, pasture, mining, etc. The relative importance and magnitude of these processes in determining nonpoint loads will vary among land use categories and associated human activities. Even within an urban region, the parameters required for the various modeling options will differ for alternative land uses. Many of these same urban modeling options have been used for non-urban land areas with parameters (e.g., constant concentrations) estimated for the specific non-urban land use.

Urban Runoff Quality Models

Five models (USGS, HSPF, STORM, SWMM, AUTO-QI), details of which may be found in Donigian and Huber (1991), collectively make up the best choice of full-scale simulation models for urban areas. Other models have been adapted from SWMM and STORM and given modified names, but the principles are fairly similar. At least two European models, MOUSE and Wallingford (Hydraulic Research, Ltd.), are available for simulating water quality. Also, there are many models well known in the hydrologic literature, such as those developed by the Hydrologic Engineering Center (HEC) and U.S. Soil Conservation Service (SCS), but this review was limited to models that directly simulate water quality. A general comparison of urban model attributes is given in Table 1. This table includes the EPA Statistical Method since it can be considered a formalized procedure.

Table 1.

Comparison of urban model attributes.

Attribute	DR3M-QUAL	MODEL HSPF	Statistical(a)	STORM	SWMM	AUTO-QI

Sponsoring agency	USGS	EPA	EPA	HEC	EPA	State of Illinois
Simulation type (b)	C, SE	C, SE	N/A	C	C, SE	C, SE
No. pollutants	4	10	Any	6	10	5
Rainfall/runoff analysis	Y	Y	N (c)	Y	Y	Y
Sewer system flow routing	Y	Y	N/A	N	Y	N
Full, dynamic flow routing	N	N	N/A	N	Y (d)	N/A
Surcharge	Y (e)	N	N/A	N	Y (d)	N/A
Regulators, overflow structures, e.g., weirs, orifices, etc.	N	N	N/A	Y	Y	N/A
Special solids routines	Y	Y	N	N	Y	N
Storage analysis	Y	Y	Y (f)	Y	Y	N
Treatment analysis	Y	Y	Y (f)	Y	Y	Y
Suitable for screening (S), design (D)	S,D	S,D	S	S	S,D	S,D
Available on micro-computer	N	Y	Y (g)	Y	Y	Y
Data and Personnel requirements (h)	Medium	High	Medium	Low	High	Medium
Overall model complexity (i)	Medium	High	Medium	Medium	High	Medium

(a)EPA procedure

(b)C = continuous simulation, SE = single event simulation

(c)Runoff coefficient used to obtain runoff volumes.

(d)Full dynamic equations and surcharge calculations only in Extran Block of SWMM

(e)Surcharge simulated by storing excess inflow at upstream end of pipe. Preasure flow not simulated.

(f)Storage and treatment analyzed analytically.

(g)FHWA study, Driscoll et al. (1989)

(h)General requirements for model insallation, familiarization, data requirements, etc. To be interpreted only very generally.

(i)Reflection of general size and overall model capabilities. Note that complex models may still be used to simulate very simple systems with attendant minimal data requirements

Since SWMM and HSPF are clearly the most versatile and most widely applicable of the models, they are briefly described below. As noted above, detailed descriptions for each of the reviewed models is provided in Donigian and Huber (1991), with shorter descriptions in Donigian et al. (1995).

SWMM. The original version of the Storm Water Management Model (SWMM) was developed for EPA as single-event model specifically for the analysis of combined sewer overflows (CSOs) (Metcalf and Eddy et al., 1971), but its scope has vastly broadened since the original release. Version 4 (Huber and Dickinson, 1988; Roesner et al., 1988) of the model performs both continuous and single-event simulation throughout the whole model; can simulate backwater, surcharging, pressure flow and looped connections (by solving the complete dynamic wave equations) in its Extran Block; and has a variety of options for quality simulation, including traditional buildup and washoff formulations as well as rating curves and regression techniques.

HSPF. The Hydrological Simulation Program - FORTRAN (HSPF) (Johanson et al., 1984; Bicknell et al., 1993) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates the watershed scale ARM and NPS models into a basin-scale analysis framework that includes fate and transport in one-dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with instream hydraulic, water temperature, sediment transport, nutrient, and sediment-chemical interactions. The runoff quality capabilities include both simple relationships (i.e., empirical, buildup/washoff, constant concentrations) and detailed soil process options (i.e., leaching, sorption, soil attenuation, and soil nutrient transformations).

Non-Urban Runoff Quality Models

The most useful non-urban runoff quality models that are currently available include: HSPF, CREAMS/GLEAMS, ANSWERS, AGNPS, PRZM, SWRRB, and UTM-TOX. HSPF was briefly described earlier as it also includes urban runoff modeling capabilities. Table 2 shows a comparison of selected non-urban model attributes and capabilities.

Table 2.

Comparison of urban model attributes.

Attribute	AGNPS	ANSWERS	CREAMS	HSPF	PRZM	SWRRB	UTM-TOX
Sponsoring agency	USDA	Purdue	USDA	EPA	EPA	USDA	ORNL & EPA
Simulation type	C, SE	SE	C, SE	C, SE	C	C	C, SE
Rainfall/runoff analysis	Y	Y	Y	Y	Y	Y	Y
Erosion Modeling	Y	Y	Y	Y	Y	Y	Y
Pesticides	Y	N	Y	Y	Y	Y	N
Nutrients	Y	Y	Y	Y	N	Y	N
User-Defined Constituents	N	N	N	Y	N	N	Y
Soil Processes							
Pesticides	N	N	Y	Y	Y	Y	N
Nutrients	N	N	Y	Y	N	Y	N
Multiple Land Type Capability	Y	Y	N	Y	N	Y	Y
Instream Water Quality Simulation	N	N	N	Y	N	N	Y
Available on Micro-computer	Y	Y	Y	Y	Y	Y	N
Data and Personnel Requirements	M	M/H	H	H	M	M	H
Overall Model Complexity	M	M	H	H	M	M/H	H
Y = Yes, N = No, M = Moderate, H = High, C = Continuous, SE = Storm Event							

Continuing model development and testing within the agricultural research community will likely lead to further enhancements of the agricultural models like CREAMS/GLEAMS, SWRRB, and AGNPS. In fact, USDA continues to support, a wide range of model development work. SWRRB development appears to be focusing on a middle ground (in terms of complexity) between HSPF and the detailed field-scale models that are limited to small areas; its use of daily rainfall, as opposed to smaller time interval measurements (usually hourly is needed for HSPF), is seen as a definite advantage by many users. However, most of these efforts still focus primarily on agricultural areas, with limited abilities to be used in large, complex multi-land use basins.

Discussion and Summary Recommendations

The models mentioned here do not represent all of the modeling options available for runoff quality simulation, but they are certainly the most notable, widely used and most operational. Selection from among these models is often made on the basis of personal preference and familiarity, in addition to needed model capabilities. As noted above, HSPF and SWMM are probably the most versatile and most widely applicable of the models, with the nod to SWMM if urban hydrology and hydraulics must be simulated in detail. On the other hand, the water quality routines in HSPF for sediment erosion, pollutant interactions and surface water quality are superior, and the capability to handle all types of land uses and pollutant sources efficiently (including urban and agriculture, point and nonpoint) is a definite advantage when needed for large complex basins. Both models appear somewhat overwhelming in terms of size to the novice user, but only the components of interest of either model need be used in a given study, the catchment schematization can often be coarse for purposes of simulation of water quality at the outlet, and they may be applied with simple water quality options with a significant reduction in data requirements.

Simulation of runoff quality will increase in importance as regulation and control of nonpoint sources continues to increase into the next century. The implementation and enforcement of various federal and state regulations will require assessment of stormwater outfalls for NPDES permits, waste load allocations (TMDLs), and appropriate control strategies that demand more detailed analyses of nonpoint contributions for comprehensive water quality management.

In spite of their more complex data requirements, conceptual models (DR3M-QUAL, HSPF, STORM, SWMM, CREAMS, SWRRB, AUTO-QI) have advantages in terms of simulation of routing effects and control options as well as superior statistical properties of continuous time series. The urban and non-urban conceptual models discussed all have a means of simulating storage and treatment effects and/or impacts of a significant number of management options. Other than a constant removal, this is difficult to do with the simpler methods. The conceptual models generally have very much superior hydrologic and hydraulic simulation capabilities. This alone usually leads to better prediction of loads (product of flow times concentration).

SWMM and HSPF retain limited support from the EPA Center for Exposure Assessment Modeling (CEAM, ceam@athens.ath.epa.gov) at Athens, Georgia, and a similar level of support is available for CREAMS and SWRRB from the USDA. Extramural support for all major operational models is highly desirable for maintenance and improvements. No model can exist for long without continuing sustenance in the form of user support, maintenance, and refinements in response to changing technology. All agencies that have sponsored, or are currently sponsoring, model development efforts need to recognize the critical importance of these activities if their efforts are to produce 'operational' models with associated wide-spread usage.

When properly applied and when their assumptions are respected, models can be tremendously useful

tools in analysis of urban and non-urban runoff quality problems. Methods and models are evolving that utilize the large and currently expanding data base of quality information. As increasing attention is paid to runoff problems in the future, the methods and models can only be expected to improve.

Primary References

(Other cited references can be found in Donigian and Huber, 1991.)

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A Compilation of Digital Geospatial Data Sets for the Mississippi River Basin

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

Digital geospatial data sets for the Mississippi River Basin have been released by the U.S. Geological Survey (USGS) on compact disc. The data sets, suitable for use with geographic information systems, are a compilation of several geographic reference data sets of interest to the global-change research community. The data sets were chosen with input from the Global Energy and Water Cycle Experiment (GEWEX) Continental-Scale International Project (GCIP) Data Committee and the GCIP Hydrometeorology and Atmospheric Subpanels. The data sets include: locations and periods of record for stream gages, reservoir gages, and meteorological stations; a 500-meter-resolution Digital Elevation Model (DEM); grid-node locations for the Eta numerical weather prediction model; and digital map data sets of geology, land use, streams, large reservoirs, average annual runoff, average annual precipitation, average annual temperature, average annual heating and cooling degree days, hydrologic units, and state and county boundaries. Also included are digital index maps for LANDSAT scenes, and for the U.S. Geological Survey 1:250,000, 1:100,000, and 1:24,000-scale map series. A listing of Hydro-Climatic Data Network (HCDN) stream gages (Slack and others, 1993) also is included and can be related to the stream-gage site file for locations and other information.

Most of the data sets cover the conterminous United States; the DEM also includes part of southern Canada. The stream and reservoir gage and meteorological station files include sites from all states having area within the Mississippi River basin, plus that part of the Mississippi River Basin lying within Canada. Several data-base retrievals were processed by state, therefore many sites outside the Mississippi River Basin are included.

A documentation file accompanies each data set, indicating the datasource, associated time frame, and other information. The stream gages, reservoir gages, and meteorological stations are divided into two separate files for currently operating or historical (discontinued) sites; sites with data for 1993 or later (1992 for the Canadian hydrometric sites) are considered currently operating unless otherwise indicated.

The data sets are provided in at least two formats: a generic or public-domain format; and ARC/INFO* export files (except the DEM). The DEM is provided in ARC/INFO Grid (version 7.0.2) format, rather than export-file format. Graphic images of the data sets also are provided in Graphics Interchange Format (GIF) files. GIF files are easily displayed on a variety of computer systems using readily available display software. These images provide a simplified view of the data sets available on the disc, and may be used for browsing purposes. The GIF files in all cases portray significantly less spatial resolution and information content than the actual data sets.

Compilation and publication of the compact disc were funded by the USGS Global-Change Research Program.

Disc Organization

The disc complies with the ISO 9660 standard for CD-ROM discs. It is intended for use with personal computers using the MS-DOS operating system. The disc is compatible with UNIX, Macintosh, and VAX computers equipped with the appropriate CD-ROM reader and software. The overall layout of the disc is:

a_readme.1st	Main documentation file
basins\	Hydrologic units of the conterminous United States, plus the boundary of the Mississippi River Basin in Canada
browse\	GIF images for browsing
climate\	Climatography of the United States, maps of 1961-90 normal temperature, precipitation, and degree days
etamodel\	Grid-node locations and description of the Eta model
geology\	Geology of the conterminous United States at 1:2,500,000 Scale

maps\	State and county boundaries, quadrangle index maps, conterminous United States
landsat\	Scene boundaries for LANDSAT paths and rows, conterminous United States and southern Canada
landuse\	Major land uses in the United States
resrvoir\	Large reservoirs of the United States
rivers\	U.S. Environmental Protection Agency river-reach file (RF-1)
runoff\	Average annual runoff in the United States
sites\	Locations of stream gages, reservoir gages, and meteorological stations, Mississippi River Basin
software\	Programs for handling map projections and compressed files
terrain\	Digital Elevation Model of the conterminous United States and southern Canada, 500-meter resolution
xportarc\	ARC/INFO export files of the above data sets

Data-Set Documentation

A README.TXT file exists in each directory, and provides an overview of the contents of the files or subdirectories in the directory. A documentation file for each data set is located in the directory with the data set, and is named with a file extension of ".DOC." The documentation files comply with the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata, dated June 8, 1994. The FGDC-compliant metadata files are very detailed descriptions of the data sets, and include a narrative section describing the procedures used to produce the data set in digital form. The FGDC-compliant metadata files are plain ASCII text files.

Distribution Information

Copies of the CD-ROM, titled "Global Energy and Water Cycle Experiment (GEWEX) Continental-Scale International Project (GCIP) Reference Data Set (GREDS)," by Alan Rea and Joel R. Cederstrand, may be purchased for $32 from the U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, Denver, Colorado 80225, phone (303) 202-4200. The CD-ROM is identified as Open-File Report 94-388.

The data sets also were released on the Internet World-Wide Web in May 1995. The Internet Uniform Resource Locator (URL) for information on the data sets is:http://nsdi.usgs.gov/nsdi/wais/water/gcip.HTML

Information on this and other geospatial data available from the U.S. Geological Survey may be found

through the National Geospatial Data Clearinghouse node on the Internet at the following URL: http://nsdi.usgs.gov/nsdi/index.html

Acknowledgments

Numerous people and agencies contributed data sets and time to make this disc possible. Steve Williams and Linda Cully, of the University Corporation for Atmospheric Research (UCAR), in Boulder, Colorado, compiled the non-USGS meteorological-stations data set. Terry Krauss and his colleagues, of Environment Canada, were instrumental in providing the Canadian hydrometric and climatological station catalogs without restrictions on the distribution. Richard Heim, of the National Climatic Data Center, provided the data and original maps of the Climatography of the United States. Kenneth Mitchell, National Meteorological Center, provided the Eta model grid. David Maidment, University of Texas at Austin, provided valuable consultation on coordinate conversions for the Eta model grid. Authors, contacts, and reviewers for all data sets are listed in the documentation files for the individual data sets.

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A Time-Scale Perspective Applied to Toxicity Assessments Performed in Watershed Management Programs and Performance Assessments

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

Watershed management, and associated assessments of performance based on quality indicators, are governed by the fundamental physical, chemical and biological/ecological processes that operate in the watershed. These processes operate over different spatial and temporal scales and may be specific to a location in the watershed. A starting point for the analysis of these fundamental processes is the recognition of the importance of watershed location on the potential influence of contaminants and land use. For example, in a low-order stream reach changes in physical and chemical conditions, as measured from baseline/baseflow conditions, will be of short duration. Although the duration of events may be short in low order streams, the magnitude of change is often great, while only limited residual effects are observed because of high transport rates out of the system. In low order streams management will often

focus on contaminant concentration, rather than loading, and the control of single sources. In addition, the potential for contamination is usually limited by the small watershed area associated with these small streams. In contrast, the change in physical and chemical conditions in high order streams will have longer durations. Although the change in physical and chemical conditions may still be rapid, the magnitude of this change will be moderated by the increased baseflow and dilution capacity of these larger streams. In high order streams, event duration is often long, reflecting the extended concentration time for flows from tributaries. In addition, the effect of contaminants can be extended because residuals are stored or only slowly transported within these larger rivers. The management focus in larger watersheds will typically shift to contaminant loading, the effects of multiple sources, and the effect that a more diverse land use has on both the number and mass loading of contaminants.

It is possible to extend this analysis of the management focus in low and high order streams to considerations of toxic potential. The disturbance of any watershed, natural or anthropogenic, is expected to produce alterations in runoff volume, and chemical characteristics of the runoff (Borman et al., 1968; Vitousek et al., 1979; Webster and Patten, 1979; McDowell, 1988; Close and Davies-Colley, 1990; Edwards and Helvey, 1991). Unfortunately, the concentration of human populations also leads to the concentration of contaminants and the proliferation of landscape/watershed disturbances both near the population center and at locations where resources are obtained to meet population needs (Goudie, 1990). The result is that water quality alterations are magnified by the combined effects of disturbance and the concentration of contaminants. The effects on receiving system aquatic life will be short-term if the natural assimilative capacity of the stream/watershed system is not exceeded and long term if deposited contaminants lead to residual effects. As noted above, watershed location (stream order) is critical in determining the relative importance of concentration or loading. When low order streams are compared with high order streams, the effects of changes in runoff volume and contaminant concentration are less likely to be moderated by ambient flows leading to acute toxicity and profound, short-term change in receiving system biota. In high order streams contaminant concentrations may not be acutely toxic, but the residual effects produced by deposition, storage, or slow transport will lead to chronic toxicity and the effects on receiving system biota will be subtle. As the ratio of disturbed to undisturbed land increases, the risk of severe impact also increases. Recent analyses indicate that any increase in impervious area above 15 to 20% will severely limit ecological integrity (Shaver, et al., 1995).

This complex set of relationships among spatial scale, duration of effect, location, and risk of impairment requires that watershed assessment and management use techniques appropriate to scale and location. The development of appropriate management techniques is dependent on the acquisition of the right information to support that management. As part of a research effort directed to the development of appropriate measures of effect/impact over connected temporal and spatial scales, a time-scale toxicity paradigm has been developed that is useful in watershed management and performance assessments. This paradigm recognizes that measuring the effect on receiving system biota, and associated measures of ecological integrity, begins with an understanding of both contaminant concentration and duration of exposure. In this paradigm, the time-scale of exposure is the starting point for selection of assessment procedures, as well as identification of appropriate management practices and performance measures.

A Time-scale Perspective

A time-scale perspective begins with defining appropriate time-scales for management activity. Although time-scales of significance can vary widely at a location, as well as in the watershed (Herricks, 1996), three time-scales are used as the starting point for toxicity assessment. A short time-scale is intended to assess effects of change within an event that produces change in the hydrology or chemistry. In this intra-event scale, concentration variation may be several orders of magnitude and exposure times may be as short as seconds, certainly minutes and possibly a few hours. The second time-scale spans an entire event, normally starting with a rise in the hydrograph, which initiates physical and chemical change, and extends some time after the event when conditions return to near baseline, typically not exceeding a few days. This event time-scale requires compositing methods to provide samples from an event that reflect average, rather than extreme, conditions. An event time-scale analysis is particularly applicable to the assessment of management practices that modify the hydrograph and "average" water quality through detention and mixing. The final time-scale is long, weeks to years, where exposure concentrations are relatively constant, and typically, low. This long-term time-scale occurs either in constantly discharging effluents, or is associated with the residuals left from single events. Since toxicity is associated with both magnitude (concentration) and duration of exposure, short-term methods of toxicity assessment are applicable to intra-event and event time-scales. In fact, intra-event time scales have required development of new toxicity testing procedures (Herricks, et al. 1994). Toxicity assessment in the long-term time-scale is appropriately measured by chronic test procedures, or procedures that address frequency of exposure over a given time period. A test for a long term time-scale must meet different criteria from those appropriate to shorter time-scale assessment. Further, it should be recognized that longer time-scales introduce greater complexity in the determination of cause and effect, requiring either a greater number of measures for confirmation of effect, or measures that require a longer time span for completion of analysis, or where sequential events must occur to produce a given effect.

Time-scale Toxicity Analyses

Current toxicity testing methods expose organisms to a constant concentration of contaminant for a given time period (usually 48-96 hours), measuring a median lethal concentration (LC50) or a median lethal time of exposure (LT50). These exposure situations only have relevance to extended event or long-term time scales in watershed assessment. To assess toxicity associated with intra-event or event time-scales where contaminant concentrations fluctuate, often changing by several orders of magnitude in short time periods, the response of organisms to short duration (less than 4 hours) contaminant exposure and fluctuating contaminant exposure (a second exposure after 72 hours) was assessed.

Laboratory experiments used the invertebrates Hyalella azteca and Ceriodaphnia dubia. Cadmium solutions ranging from 0.06 mg/L - 11.8 mg/L and zinc solutions ranging from 0.032 to 1.6 mg/l were used at exposure periods of 15, 30, 60, 120, and 240 minutes. Twenty organisms were exposed in each test. The exposure times were chosen to represent typical exposure periods observed in storm events. After the prescribed exposure period, organisms were removed from the contaminant, placed in a rinse container to dilute and remove residual contaminants, and finally placed in clean freshwater for a post

exposure observation period. During the post exposure observation period, mortality was monitored and recorded for up to 6 days past initial exposure. In one test series a second exposure followed the initial exposure. In these tests, an initial exposure of 15 or 60 minutes was followed by a second exposure of the same time, at the same concentrations, 72 hours following the initial exposure.

Die-off curves were plotted for each experiment, Figure 1. The general result found that mortality did not occur during the exposure period, rather mortality began after organisms were transferred to clean water and continued for up to 120 hours (or five days) after an initial exposure period of only 15 to 240 minutes. Repeat exposures produced little additional mortality in test organisms, Figure 2.

This series of time-scale toxicity experiments illustrates the critical importance of selecting test systems and measurement outcomes specific to the time scale of the disturbance. The results suggest that commonly used toxicity testing techniques (long exposure times to constant concentrations) will not adequately predict short term toxicity. Management strategies must consider both the concentration and duration of exposure to contaminants, which will vary with watershed location. In addition, test systems must be selected that have a response time appropriate to the exposure time and conditions. A time-scale perspective requires new approaches to the selection of management practices to meet specific watershed protection goals or performance requirements, which will be location specific.

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Landscape Characterization For Watershed Management

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Streams and rivers serve as integrators of terrestrial landscape characteristics and as recipients of pollutants from both the atmosphere and the land; thus, large rivers are especially good indicators of cumulative impacts. Allan and Flecker (1993), who have identified six major factors threatening the destruction of river ecosystems, state that various transformations of the landscape-hydrologic changes to streams and rivers resulting from changes in land use, habitat alteration, and nonpoint source pollution are probably the most widespread and potent threats to the well-being of lotic ecosystems. Landscape ecologists seek to better understand the relationships between landscape structure and ecosystem processes at various spatial scales (Turner, 1989). Understanding how scale, both data resolution and geographic extent, influences landscape characterization and how terrestrial processes affect water quality are critically important for model development and translation of research results from experimental watersheds to management of large drainage basins.

Measures of landscape structure are useful to monitor change and assess the risks it poses to ecological resources (Hunsaker et al., 1990). Many studies have shown that the proportion of different land uses within a watershed can account for some of the variability in surface water quality (DelRegno and Atkinson, 1988; Omernik, 1977; Reckhow et al., 1980; Sivertun et al., 1988). Hunsaker and Levine (1995) showed that both proportion of land uses and the spatial pattern of land uses is important for characterizing and modeling water quality; however, proportion consistently accounted for the most variance (40% to 86%) across a range of watershed sizes (1000 to 1.35 million ha).

The U.S. Environmental Protection Agency (EPA) is performing a demonstration of its Environmental Monitoring and Assessment Program (EMAP) for the Mid-Atlantic Region (Figure 1). One activity, the Mid-Atlantic Integrated Assessment, is designed as a collaborative initiative between EPA's Office of Research and Development and EPA's Region III (Kepner 1995). The U.S. Geological Survey developed a 4-level watershed classification scheme for the United States (Seaber et al., 1984). These watersheds are called hydrologic units, and each one has a unique code. In this paper we use the third level of watersheds, Accounting Units, as our analysis units. There are 352 Accounting Units in the United States. Our Mid-Atlantic Region contains 18 of these units or watersheds (Figure 1) which range in size from 14,550 to 38,890 sq km.

This paper outlines the application of landscape pattern metrics for monitoring and assessing regional water quality. Regional water quality was characterized using commonly measured parameters such as total nitrogen, total phosphorus, conductivity, and sediments. Water chemistry data were retrieved from the EPA's STORET (STOrage and RETrieval) database. Land-use/land-cover data came from the Advanced Very High Resolution Radiometry (AVHRR) satellite imagery with a resolution of 1 sq km and a simple classification scheme, Anderson Level 1: urban land, agricultural land, rangeland, forest land, water, wetland, and barren land.

A watershed is typically characterized by the proportion of the watershed covered by each land use of interest (Table 1); however, the spatial pattern of that land use is thought to be equally important for some ecological processes (Hunsaker and Levine, 1995). Landscape ecologists have proposed many metrics of spatial pattern that may be useful for monitoring ecological condition (Hunsaker et al., 1994; Riitters et al., 1995). Landscape pattern was characterized by proportion of the seven land-use types and several integrative metrics. Dominance measures the extent to which one or a few land uses dominate the landscape, and contagion measures the extent to which the landscape is fragmented. These metrics can range from 0 to 1. Shape complexity is a perimeter to area ratio for each patch of a land use; natural land covers like forest are expected to have higher shape complexity than agriculture patches which usually have more uniform, linear edges. Shape complexity can range from 0 to 2, but we seldom see values less than 1.0 or larger than 1.8 with real landscapes. These metrics are calculated after identification of all patches of the same land use; a patch is an area or polygon of the same, contiguous land use class. The percent of potential edges tells us how many of the edge types (i.e., forest and wetland edge or agriculture and urban edge) that could exist, given the number of land uses, actually do occur; one can think of this as a measure of edge heterogeniety.

Table 1. Percent of watershed in each land-use class for the Mid-Atlantic Region. Watershed are the USGS Accounting Units. If no value is given the percent is less than 1.

Accounting Unit	Urban	Agricultural land	Rangeland	Forest land	Water	Maximumland dominance (a)
20401	2.0	22.2		75.6		69
20402	11.1	52.0		25.3		13
20501	1.5	19.3		79.0		74
20502		20.5		78.9		75
20503	1.6	37.9		59.6		41
20600	3.8	42.9	1.1	25.4	26.6	34
20700	3.3	12.0		81.1	3.6	76
20801	1.2	12.8		59.6	25.1	55
20802	2.7	7.4		87.9	1.9	80
30101	1.5	18.1		79.8		74
30102		39.2		47.2	12.9	25
30201		33.2	1.0	26.5	38.0	37
30202	2.2	59.0		36.0	2.7	46
50100	1.6	10.5		87.6		87
50200	2.9	4.9		92.0		92
50301	5.4	21.9		71.6	1.1	68
50302		3.6		95.9		96
50500		1.0		98.4		98

a Area of largest patch divided by area of hydrologic unit.

Table 2 lists some of these landscape metrics for the Mid-Atlantic Region. Disturbed land covers like agriculture, barren, and rangeland have positive associations with water-quality parameters; that is, as the proportion of agriculture increases, so does the amount of nitrogen or sediments. Contagion and proportion of forest were found to be negatively correlated with water-quality parameters (Hunsaker and Levine, 1995). Thus, an area that has contiguous land covers (is not fragmented) or that is dominated by forests tends to have better water quality.

Table 2. Integrative pattern metrics by USGS Accounting Units in Mid-Atlantic Region.

Accounting Unit	Number of land uses	Dominance	Contagion	Shape complexity	Number of patches	Percent of potential edges
20401	5	0.6	0.62	1.45	468	90
20402	5	0.25	0.62	1.46	604	90
20501	5	0.64	0.65	1.5	946	80
20502	4	0.61	0.57	1.49	387	83
20503	5	0.51	0.6	149	761	80
20600	7	0.36	0.65	1.49	810	71
20700	5	0.59	0.61	1.45	764	100
20801	7	0.47	0.59	1.45	588	86
20802	6	0.73	0.59	1.39	323	93
30101	5	0.64	0.53	1.5	560	90
30102	7	0.47	0.68	1.51	765	71
30201	7	0.38	0.62	1.44	707	81
30202	6	0.52	0.63	1.49	470	93
50100	4	0.69	0.46	1.48	706	100
50200	5	0.79	0.61	1.35	362	80
50301	5	0.52	0.52	1.52	724	90
50302	4	0.86	0.49	1.34	140	100
50500	4	0.94	0.61	1.26	127	100

The Mid-Atlantic Region is heavily dominated by forests when characterized by AVHRR data and seven land use classes. In general, agriculture is the second largest land use although water makes up a large proportion of some of the hydrologic units that contain the Chesapeake Bay. We focus on describing a few of the hydrologic units to highlight their similarities and differences, but all of the data are presented in Tables 1 and 2. The Upper Ohio-Little Kanawha (50302) and the Kanawha (50500) are almost totally dominated by forests, the largest patch accounts for more than 95% of the watershed (Table 1), and there are a small number of total patches compared to the other watersheds (Table 2). Thus it is not surprising that these hydrologic units have a high dominance value (Table 2). They only contain four of the seven land uses and have all of their potential edge types. One difference between the two watersheds is that the patches in 50500 are significantly more contiguous with a contagion value of 0.61 as compared to 0.49 for 50302. The shape complexity values are low, 1.26 and 1.34, considering that forest patches are very dominant. The Lower Delaware watershed (20402) is extremely different from the Upper Ohio and Kanawha watersheds. It has a lot of patches (604) that are very contiguous (0.62), but it is not dominated

by a single land use with a dominance value of 0.25 for five land uses. Its largest patch only makes up 13% of the watershed. The Lower Delaware has the highest proportion of disturbed land use with 11% urban and 52% agriculture; we expect that it will have poor water quality compared to those watersheds that are dominated by contiguous forest patches. The Albemarle-Chowan watershed (30102) contains all seven land uses, has similar amounts of forest and agriculture, and thus has a moderate dominance value (0.47). It has a large number of patches with the largest patch accounting for 25% of the watershed. It has high contagion and shape complexity and has low edge heterogeniety.

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Watershed Analysis and Management: The Importance of Geology

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A watershed-based approach for the management of public lands is being adopted by federal government land management agencies. Watershed analysis is the primary tool that provides the basis for a scientifically sound understanding of watershed conditions and management options. A primary step in watershed analysis is stratification, i.e., identifying areas that can be evaluated as uniform units (U.S. Forest Service, 1994). The most useful stratification criteria are those that control distribution of conditions and rates of processes. This paper provides an overview of how geology may literally be the most underlying factor controlling watershed processes and conditions.

Conceptual Model of Interacting Watershed Elements

A watershed may be treated as an open system_with inputs, outputs, and measurable physical conditions_which describe the state of the system. Figure 1 diagrams the conceptual watershed model used in this paper. Geology and climate are the two independent factors or system inputs which influence watershed condition. Watershed vegetation, soils, hydrology, and morphology are dependent upon geology, modified by the climatic conditions, and are interdependent upon each other, as indicated by the arrows in Figure 1. Geology is an inherent watershed factor that does not change with time and which is unaffected by climate, the four interdependent factors, or land use practices at a human time scale. Climate and the four interdependent factors are ephemeral and may change during a period of several

years to several decades. Land- and water-use potential are a function of these two independent and four interdependent factors. Watershed condition at any given time results from an integration of these six natural factors and land and water use practices. Land and water use practices may affect_through feedback mechanisms_the states of the four interdependent variables, but they do not affect geology or climate.

Because it is an inherent, usually constant factor over extensive areas of a watershed, geology should be a first choice for watershed stratification. Geologic conditions are readily mapable, and, except for unusual situations, need to be mapped only once, whereas some resources may change with time due to climatic or anthropogenic changes. Finally, geologic conditions are critical for they directly or indirectly affect many watershed conditions.

Geology and Geologic Controls

Geology, for the purposes of watershed analysis, essentially can be described by two parameters: rock unit lithology and geologic structure. Lithology describes the physical properties of a rock unit, whereas structure describes the rearrangement of a rock unit by tectonic forces. The principle unit used by geologists for mapping rock bodies is the formation. A formation is a body of rock that consists of a certain lithologic type or combination of types; it may be igneous, sedimentary, or metamorphic and be consolidated or unconsolidated (American Geological Institute, 1984). Many rock units originate as horizontal, sheet-like features which may extend over tens to tens of thousands of square kilometers, and range from a few meters to several kilometers in thickness. However, near-surface exposures of formations are typically much less extensive, ranging from only several to several hundred square kilometers as a result of burial or erosion. Tectonic forces generated within the earth cause displacement of crustal rocks and the development of structural features across rock units.

Lithologic Controls

For watershed and landscape analysis, two lithologic characteristics of rocks are of greatest importance: rock strength and hydraulic conductivity. Numerous classification schemes have been devised to describe rock durability, strength, hardness, or resistance to weathering. Compressive strength determined by subjecting a rock sample to uniaxial (unconfined) compression testing is one generally accepted measure of rock strength. Although lab tests of strength are most accurate, simple field tests using a Schmidt hammer or rock hammer may be used as indices to rock strength (West, 1991). Rock strength, measured in units of million newtons per meter^2 (MN/m^2), ranges to over 150 for extremely strong rock (granite, basalt) to well under 100 for weak rock (shale, sandstone). Unconsolidated formations such as dune sands, loess, or glacial till usually have strengths of 1 MN/m^2 and less. Conditions such as fracturing or weathering may substantially reduce strength.

Hydraulic conductivity (or permeability) is the rate at which water moves through a porous medium under a unit potential-energy gradient. It is primarily a function of the cross-sectional area available for water transmission for saturated groundwater conditions, and is also a function of degree of saturation for

unsaturated conditions. Generally, saturated hydraulic conductivity increases with increasing grain size and sediments of uniform grain size. Interlocking grains or crystals, as in igneous rocks, yield extremely low conductivities, whereas unconsolidated deposits generally have high conductivities. Conductivities may be very high where solution has dissolved rock and provided large flow pathways, as is often the case for carbonate rock units.

Figure 2 illustrates a plot of rock strength versus hydraulic conductivity for several major rock types. The plotted values are median values; not shown on the diagram is the large range over which the two parameters may vary for a given rock type depending on specific conditions of a particular rock body.

Structural Geology Controls

Deformations of the earth's crust are manifested in rock units as faults (displacement along fractures), joints (brittle fractures with no displacement), and folds (plastic flexures). Faulting and folding provide for initial topographic relief and may differentially raise or lower formations with respect to one another. Faults and areas of fractured rock are weaker and more subject to erosion than unfractured rock. Because of this weakness, these areas may form topographic low spots and control the drainage network of a watershed. Likewise, interbedded stronger and weaker rock formations may be exposed at the surface by fold structures, with the stream network influenced by the outcrop pattern of the rock units. Examples of Geologic Controls on the Watershed

Watershed Morphology and Sediment Yield

The bedrock underlying a watershed and soils derived from that bedrock have a significant effect upon watershed morphology. Stronger rocks provide the opportunity for greater relief, whereas weaker rocks generally create low-relief topography. Geologic structures may define the pattern of the drainage network. Soil permeability and infiltration rates roughly correlate with hydraulic conductivity. Drainage density is inversely correlated with permeability, and has been shown to be related to bedrock geology in a region of climatic similarity (Hadley and Schumm, 1961).

Runoff Hydrology

Geology affects hydrograph characteristics including mean annual runoff, baseflow, and flood hydrology. Little surface runoff occurs from highly permeable dune fields or karstic carbonate rocks, whereas these areas may sustain a near-constant year-round baseflow. However, in areas where structural folds cause bedrock to dip away from the watershed outlet, baseflow may be reduced because groundwater movement is not coincident with watershed topography.

Flood runoff is more efficient and more quickly reaches a watershed outlet when drainage densities are higher. Since drainage density is inversely related to the hydraulic conductivity of the underlying bedrock and derived soil, watersheds underlain by impervious shales should produce higher peaks than

those underlain by pervious sandstones. An investigation of 35 watersheds in Wyoming and Colorado reveals runoff and peak discharge to be directly related to the bedrock geology of the watersheds.

Water Quality

Rock unit chemistry directly influences water quality, as water flowing over or through a rock unit and its residuum dissolves salts from the unit. Analysis of stream water quality for northeast Wyoming reveals that the waters can be classified into six distinct categories based upon major ionic constituents. Grouping water quality sample sites by water quality categories shows a direct correspondence with the bedrock geology underlying the source watershed.

Stream Character

Throughout much of the western United States, the U.S. Forest Service is stratifying stream segments using a stream classification procedure devised by Rosgen (1994). Slope, sinuosity, entrenchment, and sediment size are characteristics used in the procedure to classify a stream as a given type. However, bedrock geology can often provide an explanation of why a stream has those characteristics. A stream's sediment size is related to sediment source rock strength and distance of transport. At a reach scale, slope, sinuosity, and entrenchment may be a function of rock strength and the stream's relationship to geologic structure. Understanding the dependencies of stream character upon the underlying geology can provide guidance in stream and watershed restoration.

Vegetation

The transition of vegetation type with climatic conditions is readily observable in mountainous regions. However, vegetation type may change even more abruptly at contacts or faults separating distinct rock lithologies. For example, in arid regions of the West, sagebrush tends to occupy shale and soft sandstone lithologies where their roots can extend in all directions to absorb moisture. Pinyon and juniper, however, occupy stronger, jointed sandstones, preferentially located along joints. In areas where plant community differentiation is dominated by geology, geologic mapping could be used for wildlife resource management planning.

Land Use

Geology may influence potential land use; an excellent example is agricultural land use within the Big Sandy Creek watershed of eastern Colorado as described by Coffin (1967). Areas of the watershed are underlain by a sandy silt loess, dune sands, or the Pierre Shale. Dryland farming in the area is restricted to the loess, which is easily tillable and has good moisture retention. The Pierre Shale is fairly impermeable and generates rapid runoff. Perennial short grasses are abundant, and grazing is possible. However, overgrazing leads to erosion and invasion by less desirable plants. Dune sands are not suitable for cultivation, for wind erosion can occur and soil moisture rapidly percolates through the sand. Dune

areas provide abundant grasses for cattle grazing.

Geology and Watershed Stratification

Stratification should be made on the basis of rock units of similar physical or lithologic character, possibly as expressed in Figure 2. Generally, the formation will be the proper rock unit for stratification; however, groups of formations or parts of formations (members) may provide rational groupings. Overlaying the bedrock stratification is a structural stratification layer, which positions faults, illustrates primary jointing directions, and shows fold axes and dip direction. At watershed sizes of 50 to 500 km^2, geologic maps with the proper resolution are typically available for much of the United States. Geology coverages can readily be incorporated into a geographic information system for concurrent analysis with other watershed elements. Lithologic units are implemented as polygons, with structural features typically specified as arcs.

Summary and Conclusions

Geology is a important factor affecting the conditions and physical processes occurring in a watershed, and in regions of climatic similarity, geology may be the most significant factor in determining potential watershed condition. Physical and ecological conditions of a watershed are often directly or indirectly related to bedrock lithology and structural geology of the underlying geologic formations. Bull (1991) indicates that seemingly anomalous conditions in a watershed may be completely explained by its geology. This paper presents several of these relationships, for they and the underlying role of geology are more than occasionally ignored in watershed, landscape, and ecologic analyses. Finally, geology makes an excellent stratification tool for watershed analysis and management for several reasons:

- Many physical and biological processes of the watershed are directly or indirectly related to the underlying bedrock geology.
- The areal distribution of geologic units is often appropriate for watershed-scale analyses.
- Geologic maps generally are readily available at scales that are useful for watershed stratification.

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Development and Application of Watershed Analysis to Washington State's Forest Lands

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Background

The State of Washington contains 12 million acres of state and private forest lands. Forest management on these lands is controlled by the Forest Practices Act enacted in 1974 and a comprehensive set of rules and regulations designed to protect public resources (Fish, wildlife, water and public improvements) while at the same time providing for a viable forest products industry.

Historically, the Forest Practices Rules only allowed for site specific reviews of proposed forest management activities. In the late 1980's, high timber prices, sales of large timber land holdings, and concerns about environmental regulation led many landowners to significantly escalate their timber harvest activities. The number of applications for harvest processed by the Department of Natural Resources (DNR) has approximately quadrupled from approximately 8,000 applications per year in 1988 to about 11,000-12,000 applications per year at present. At one point, the numbers exceeded 16,500 applications per year.

During this time period, concerns were expressed on a number of fronts about the potential cumulative effects of this increased logging activity. In addition, data from forest lands indicated fish habitat degradation, significant changes in fish stock viability, and poor water quality. Reviews of the forest practices regulations as part of a legal challenge revealed that the state was unable to prevent cumulative impacts and the resulting public resource losses without a change in the rule structure.

The Washington State Forest Practices Board and Department of Ecology jointly adopted cumulative

effects rules in 1992. With the help of participants under the Timber, Fish, Wildlife Agreement (TFW), the need for rule changes was evaluated and a new rule framework was designed. At the same time, TFW scientists were developing the first version of the technical manual used to implement the rules. The focus was limited to fish, water and public improvements in the initial stages due to concerns about methodologies and implications of wildlife. The result was Watershed Analysis (WA).

Overview

Watershed analysis has many attributes. First of all it is scientifically based. The best available knowledge of watershed and ecosystem needs has been assembled and documented in a comprehensive evaluation. The analysis process has been broken into two levels of detail to accommodate watershed of a variety of complexities.

Second, watershed analysts must be qualified to participate in the process. Each technical area in watershed analysis has a set of qualifications based on experience. In addition, qualification requirements include completion of a training program.

A third attribute is the basin specific focus. Forest lands in the state have been broken up into Watershed Administrative Units (WAUs) based on hydrologic and geomorphic considerations. Each WAU is between 10,000 and 50,000 acres in size, an areas deemed to be manageable in terms of information and decision making. The WSA process can be initiated by the DNR, or by any landowner within a WAU owning 10% or more of the drainage.

Finally, WSA has a logical link to the other forest practices rules. In all watershed analyses, the analyst knows that the minimum protection for all areas on the landscape is provided by the standard forest practices rules. WSA indicates where additional protection is needed. This leads to basin specific management and increased predictability for all those concerned.

The Watershed Analysis Process

The four key process steps in WA are: Start-Up, Assessment, Synthesis and Prescriptions (see Figure 1). The process is usually overseen by a watershed analysis leader who keeps people on schedule and makes sure the proper steps are followed and adequately documented.

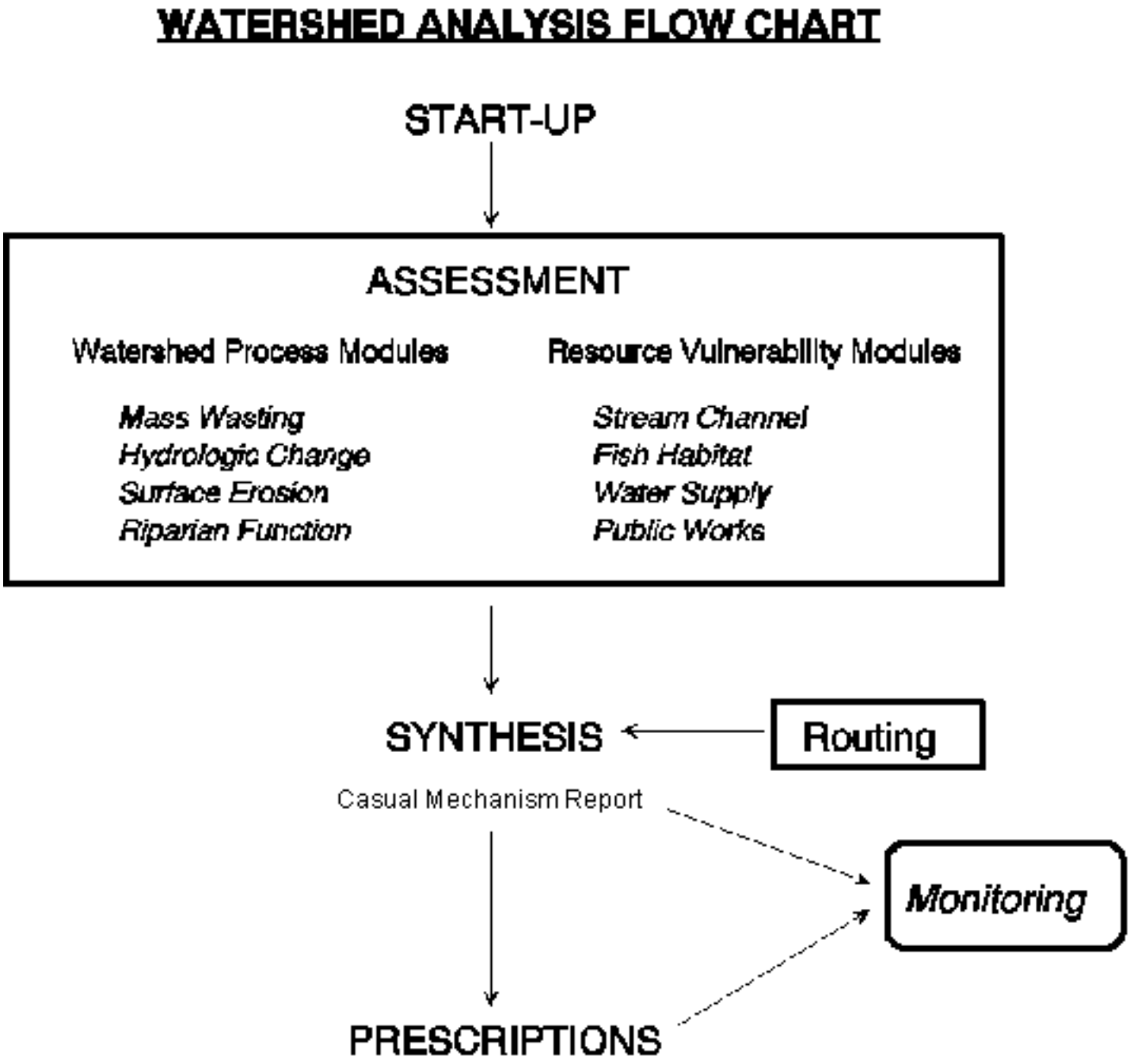

Figure 1. Watershed analysis flow chart.

The Start-Up step primarily involves identification of team members and assembly of needed resources (maps, data, equipment). Teams are established for each technical aspect of the assessment process, plus synthesis and prescriptions. Lastly, the initial level of analysis (Level I or II) is determined.

The Assessment step is the most complex part of Watershed Analysis. It involves three primary activities: data collection, analysis, and decision making. During this step, analysts must assess the environmental effects of forest management activities on fish habitat, water quality, and capitol improvements, and determine the hazards on the landscape.

Seven "Modules" are used to assemble the necessary information and direct the decision making. There are four watershed process modules. These address mass wasting, surface erosion, hydrology, and riparian function. They assist the analyst in evaluating the following types of input variables: water, wood, coarse sediments, fine sediments, and energy (heat).

Three resource modules focus on collecting information on fish use and habitat characteristics, water supplies (domestic, irrigation, and fish hatcheries) and capital improvements (public roads, bridges, power lines, etc.). Finally, a channel module acts as an integrator of the process and resource concerns by indicating the dynamic character of the channel.

The resource modules provide two critical pieces of information. The first is resource "vulnerability"-a qualitative measure of the sensitivity of a resource to change based on present condition at a specific location. A rating system using high, medium and low vulnerability is used. The second piece of information is a map showing the location of all vulnerable resources in the basin. It is used later in the synthesis process.

In the next step, the analyst determines the likelihood of "delivery" of a hazard to a stream. Deliverability is defined as "the likelihood that a material amount of wood, sediment, or energy will be delivered to fish, water, or capital improvements of the state." Tools are provided for evaluating landscape features and predicting delivery at various confidence levels.

When the assessment process is completed, the information from each module is collected by the module team leader. This person assembles the information and verifies the technical quality of the products. The end products of Assessment include a standard format report which prepares the analysts for synthesis. In addition, 1:24000 level base maps are prepared with either watershed hazards (process modules) and resource information.

Synthesis is the next activity. The team leaders of each of the modules assemble and summarize the hazard and resource vulnerability information. The primary activity in Synthesis is the "routing" exercise-an evaluation of cause and effect. Analysts review the hazard and vulnerability information, then determine the likelihood that a deliverable hazard will materially change a vulnerable resource. Where deliverable hazards are likely to impact vulnerable resources, an "area of resource sensitivity" is indicated on the map (See Figure 2).

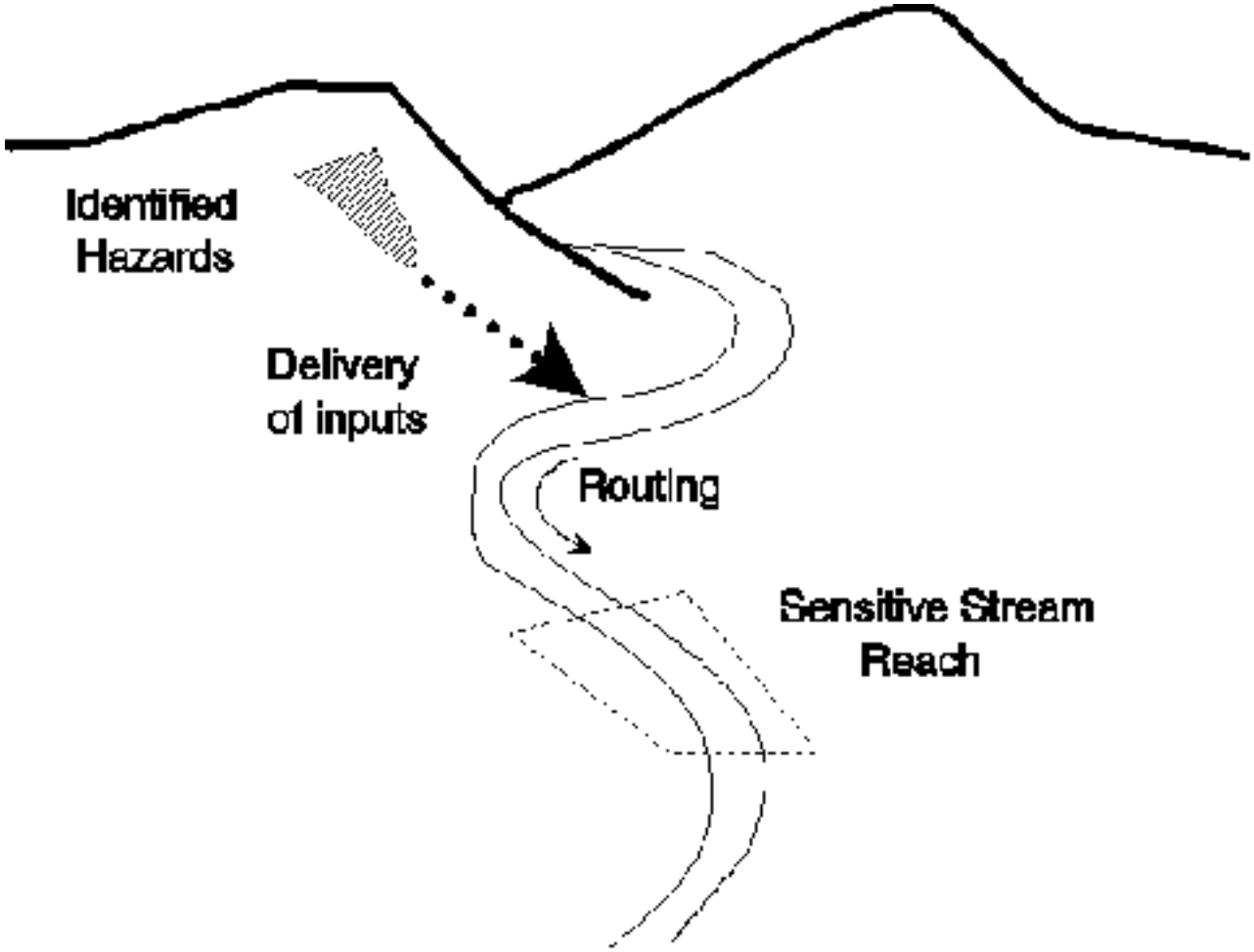

Figure 2. Determining the relationship of watershed hazards to vulnerable resources.

The next step in the Synthesis process is called the "Rule Call". Table 1 is used to compare the vulnerability rating to the delivered hazard rating for a given area. It indicates whether activities in the future should be managed under current rules or not. If not, activities will need to be more strictly regulated so that they minimize, prevent, or avoid impact to vulnerable resources.

Table 1. Vulnerability rating as compared to delivered hazard.

		Delivered Hazard		
		Low	Medium	High
Vulnerability	Low	Standard Rules	Standard Rules	Prevent or Avoid
	Medium	Standard Rules	Minimize	Prevent or Avoid
	High	Standard Rules	Prevent or Avoid	Prevent or Avoid

For each area where the rule matrix calls for minimize, prevent or avoid, a causal mechanism report must be prepared. This report describes sensitive areas using a standardized format including a statement called the situation sentence-a statement that links the hazards, management activities, and resource vulnerabilities together.

For each causal mechanism report a set of prescriptions are identified by the Prescription Team. The team is made up of forest management and resource professionals who have been certified to do this part WA. The sponsor of the WA is encouraged to include representatives from the landowners, state agencies, Indian tribes and other interested and affected parties in the design of prescriptions.

The last step in the process is to develop a monitoring plan. At the present time, development of this plan is voluntary. However, a module has been prepared to assist watershed analysis teams. The plans are designed to evaluate key resource issues and watershed processes identified in the analysis process. New mechanisms are being explored to ensure that monitoring occurs.

Once the monitoring plan is completed, a final report is assembled including all the maps and decision documents. This report is peer reviewed, then sent out by the DNR for formal public review under the provisions of the State Environmental Policy Act. Comments are taken and if no modifications are needed, the watershed analysis is approved. DNR then uses the information in the watershed analysis (primarily in GIS map form) to review forest practices applications. The prescriptions are voluntary and applications including the prescriptions are given a minimium review by agencies. Applications from landowners choosing to not follow the prescriptions are reviewed under the rigorous State Enviromental Policy Act rules-a broad evaluation of potential impacts resulting from the planned activity.

Each watershed analysis is expected to be reviewed every five years. At these reviews, DNR will assist the sponsor in determining the effectiveness of their prescriptions. Needs for changes in prescriptions will be evaluated and modifications can be made at that time.

Summary

Many benefits have been identified in watershed analysis. They include managing on a basin level, predictability for all parties, reduced processing time for permits, reduced workload in day-to-day management, and a scheduled evaluation of effectiveness.

Currently, watershed analysis is underway or complete in approximately fifty-five WAUs. This is a small portion of the 800+ WAUs in the state, however, we believe it is a good start for only three years of implementation.

The process is gaining interest and more people are being qualified to conduct the analysis each year. Adaptive management is being used to constantly hone the modules and new pieces are under development at this time, mainly focused on water quality and wetlands. Finally attempts are being made to link watershed analysis with Habitat Conservation Plans (HCPs) and Total Maximum Daily Loads

(TMDLs).

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Structural Best Management Practices for Storm Water Pollution Control at Industrial Facilities

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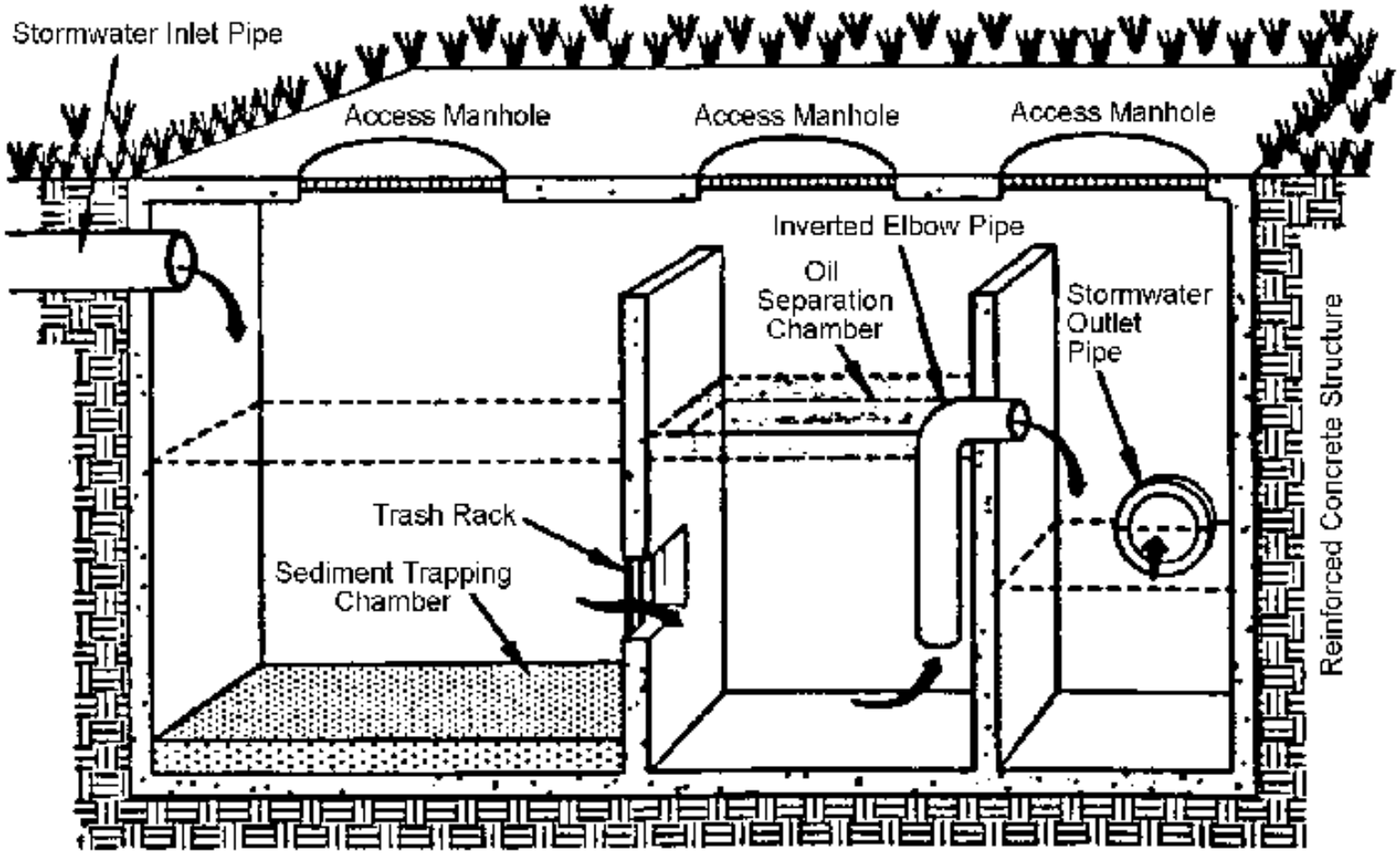
Introduction

Storm water management at industrial facilities generally focuses on minimizing the contact of manufacturing materials with wet and dry weather flows through improved spill control, pollution prevention, and isolation of identified sources. In some cases, these best management practices (BMPs) may not completely prevent storm water contamination and on-line and/or off-line structural BMPs may be needed to capture pollutants before they migrate off-site. U.S. Environmental Protection Agency (EPA) has developed guidance on structural BMPs for industrial activities (USEPA, 1992). In 1993, EPA investigated the performance, effectiveness, reliability, and cost of four BMPs: water quality inlets, sand filters, infiltration trenches, and wet detention ponds. This work included an evaluation of the BMPs at selected industrial facilities nationwide. The primary objective was to identify factors that influence the selection of structural BMPs for industries, particularly the performance, limitations, longevity, design criteria, maintenance requirements, costs, and environmental impacts.

Description of BMPs

Water Quality Inlet

As shown in Figure1, water quality inlets consist of a series of chambers that remove sediment, screen debris, and separate free oil from storm water. Water quality inlets are designed to capture the first flush of runoff. This BMP is particularly well-suited to capture particulates and hydrocarbons from small, highly impervious areas, such as loading areas, parking lots, and gas stations. Water quality inlets can be purchased as pre-cast units or can be constructed on site.



Source: NVPDC, 1992.

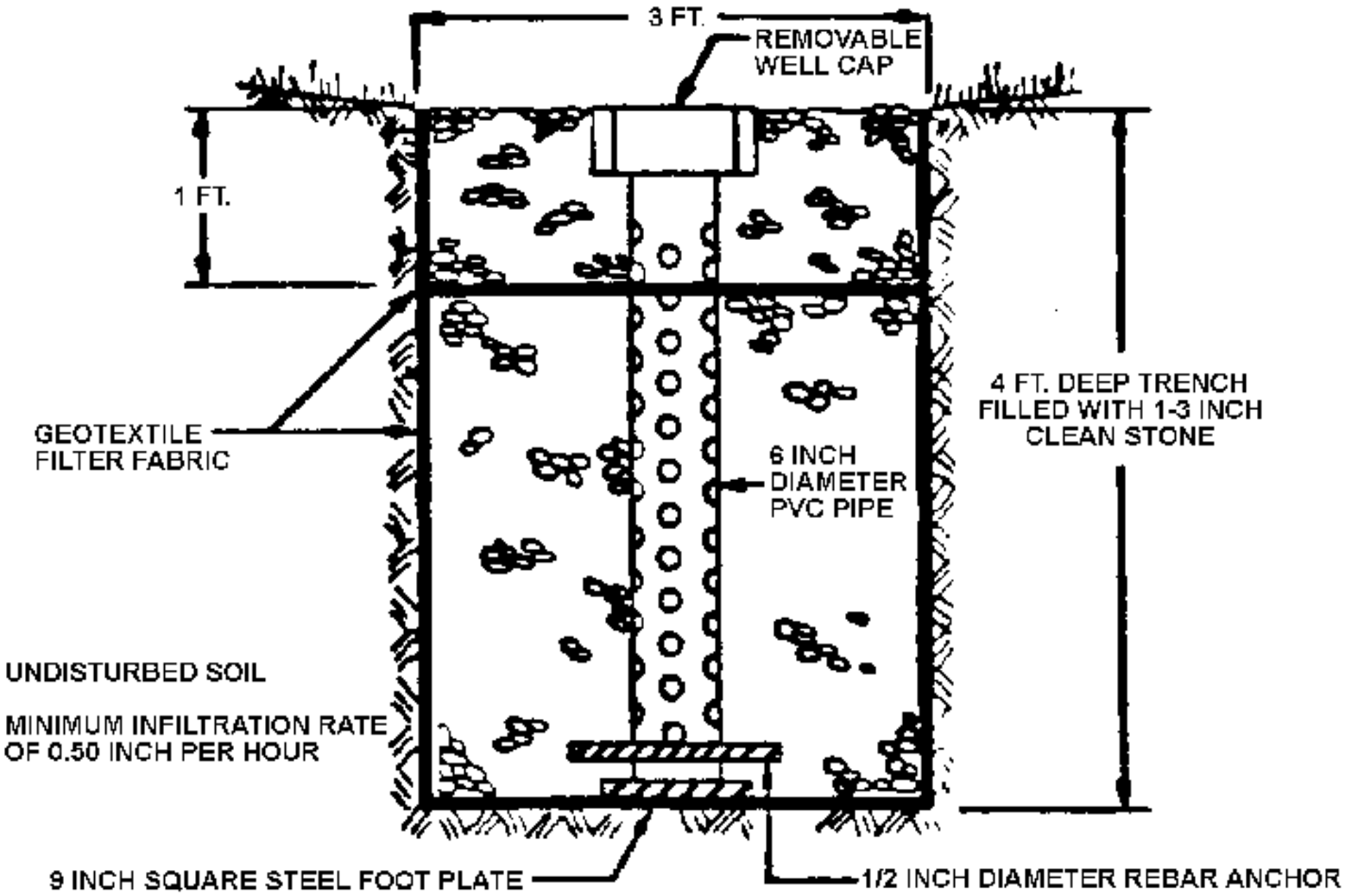
Figure 1. Profile of a Typical Water Quality Inlet.

Water quality inlets are commonly used where land constraints prohibit the application of other BMPs or where pretreatment of a portion of the runoff is desired. These devices are generally used in an off-line configuration (i.e., only part of the runoff is diverted to the inlet). On-line units may not perform as well because of the increased turbulence of higher flows that cause resuspension of settled material in the sedimentation chamber.

Infiltration Trench

Infiltration trenches are designed to capture and filter small amounts of runoff, preferably the first flush. As shown in Figure 2, an infiltration trench is an excavated trench, 3 to 12 feet deep, containing stone aggregate with, perhaps, pea gravel in the top layer. Pollutant removal is achieved by filtration through the surrounding soils. Trenches can achieve up to 90 percent removal of particulates, metals, organic compounds, and bacteria. Moderate removal of biochemical oxygen demand (BOD), nitrogen and phosphorus is also possible. Pollutant removal may be enhanced by adding organic material and loam to the trench subsoil.

Preferred site characteristics include low surrounding slopes, well-drained soils overlying a deep water table and bedrock, and revegetated (undisturbed) drainage areas. Upstream BMPs may be needed to pretreat runoff to remove sediments or hydrocarbons that may clog the trench. Soil infiltration is the primary pollutant removal mechanism; therefore, groundwater contamination is a concern. Industries can minimize the introduction of toxic and hazardous materials in the runoff by isolating areas of concern or by diverting flows from these areas away from the trench.



Source: SEWRPC.

Figure 2. Infiltration Trench

Wet Detention Ponds

Wet detention ponds provide both quality and quantity control of storm water. A wet detention pond maintains a permanent pool (see Figure 3) where long-term treatment of pollutants occurs by physical, biological, and chemical processes. Sediment and particulate metals are removed by sedimentation and dissolved metals and nutrients are removed by physico-chemical action and biological uptake. Typically, a sediment forebay is included to capture heavy sediments that would otherwise fill in the permanent pool. The addition of shallow ledges or wetlands around the pool allows the growth of aquatic plants that enhance nutrient removal.

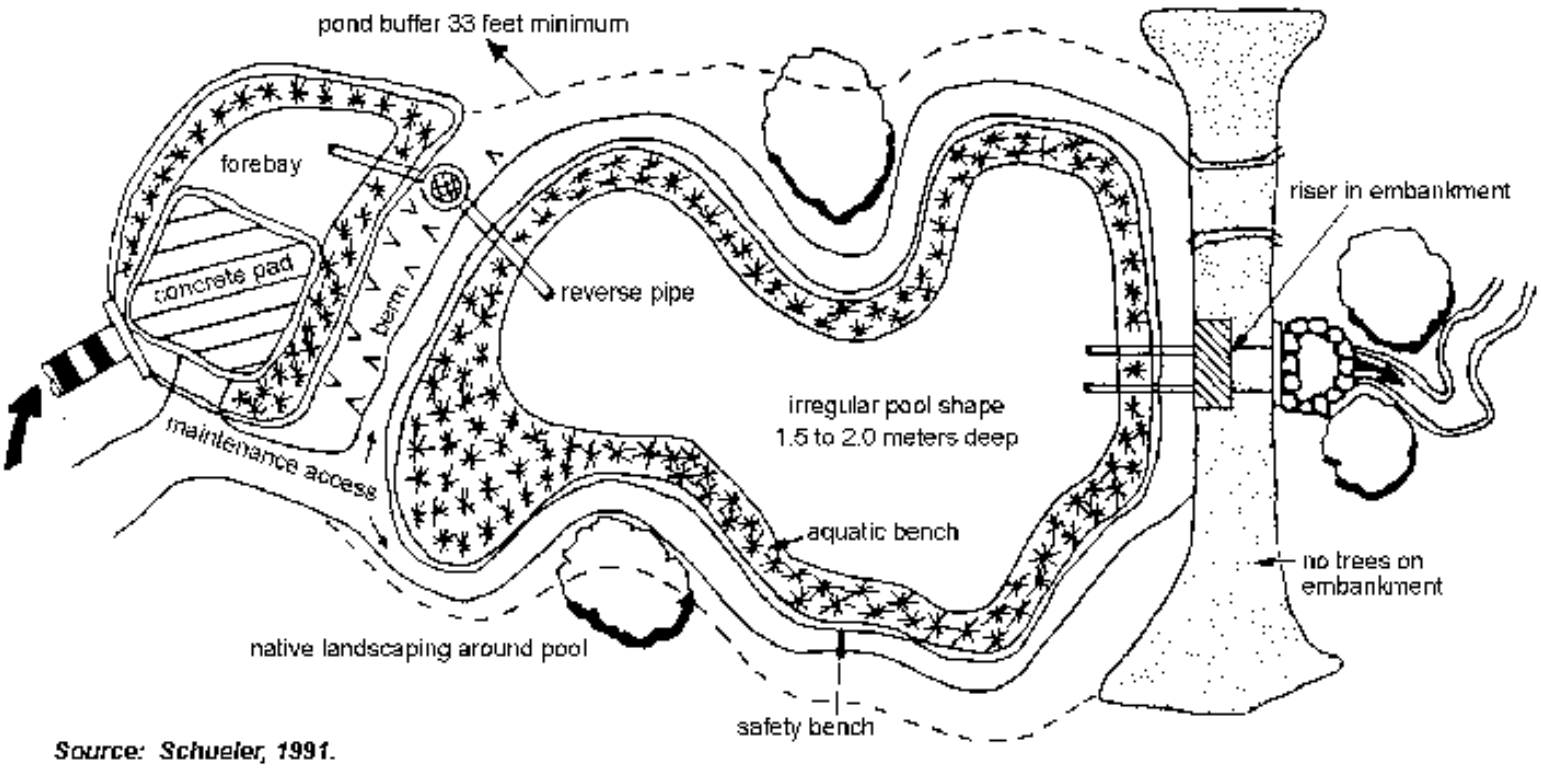


Figure 3. Schematic of Enhanced Wet Detention Pond.

Wet ponds must maintain a permanent pool; therefore, the drainage area should receive sufficient rainfall and relatively impermeable soils should be used in construction. Adequate land area must also be available for the pond and associated easements.

Sand Filter

There are several variations of sand filters, including surface and underground and on-line and off-line systems. The Washington, D.C. sand filter, shown in Figure 4, is an underground unit consisting of a sedimentation chamber for sediment and floatables removal and a filtration chamber for removing pollutants associated with particulates. Sand filters can achieve high removals of sediment, BOD, and coliform bacteria. Metals removal is moderate and nutrient removal is low. However, a peat layer can be added in the filtration chamber to improve the removal of these pollutants.

Sand filters are recommended for highly impervious areas where land availability is limited. Washington, D.C. sand filters are used to treat runoff from airports, loading areas, storage yards, vehicle maintenance garages, and service stations. This BMP may substitute for water quality inlets in areas where lower sediment loads occur.

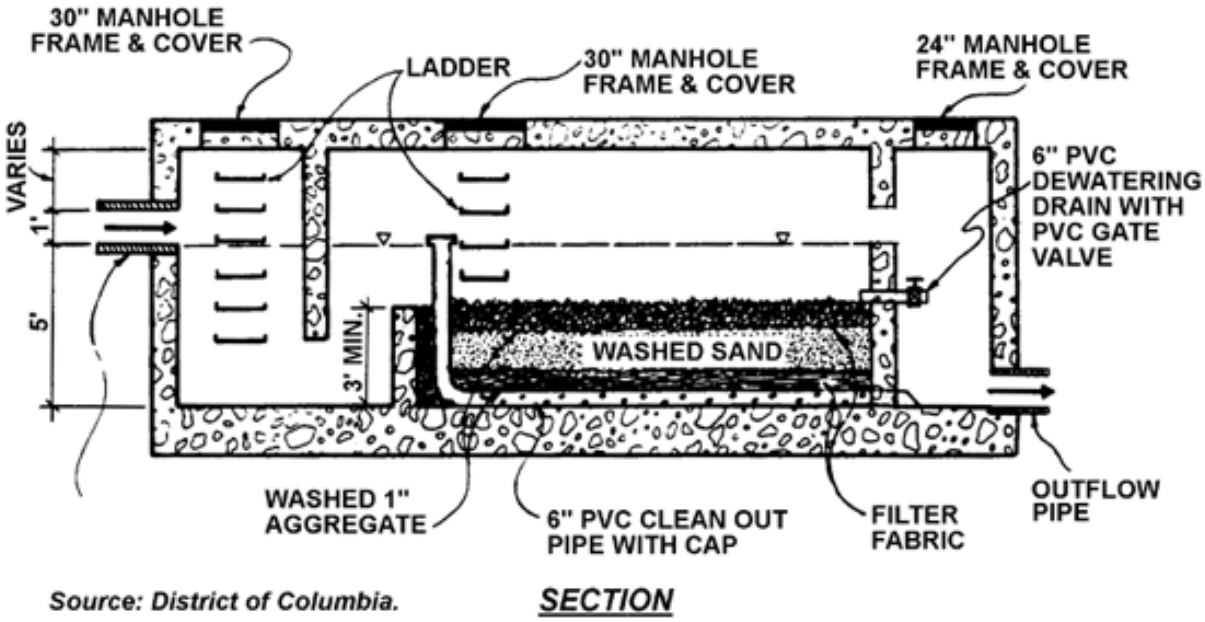


Figure 4. Washington, D.C. Sand Filter.

Factors Affecting the Selection of BMPs for Industrial Activities

A summary of the factors affecting the selection of the BMPs is presented in Table 1. Each of these factors is discussed below.

BMP	Applications	Limitations	Longevity	Maintenance	Construction Costs	Environmental Impact
Water Quality Inlet	Stand alone or pretreatment device Drainage area <1 acre Short detention time	Not appropriate for disturbed areas Routine maintenance is essential	Long life span: 95% operate as designed in first 5 yr Lack of regular clean-outs limits effectiveness	Inspect each season and after major storm events Clean out sediments and debris	$5,000 to $16,000 for cast-in-place Pre-cast are less expensive	Efficient removal of debris, sediment, and hydrocarbons Residuals may require disposal as a hazardous waste
Infiltration Trench	Drainage area <10 acres Must receive low sediment/oil & grease loads Soil infiltration rate >0.5 in/hr	Infiltration rate reduced in freezing conditions Potential for clogging Must prevent groundwater contamination	Short life span: >50% fail in 5 yr Increased by proper site selection, use of pretreatment BMPs, and maintenance	Inspect annually and after large storms Monitor drainage rate Replace clogged media	$3,000 to $8,500 for 3 ft deep x 4ft wide (1,200 cu ft)* $8,000 to $19,000 for 6 ft deep x 4ft wide (2,400 cu ft)*	Efficient removal of particulates, coliform bacteria, organics, nutrients and some soluble metals

	Water table depth >4ft					Potential for ground water contamination
Wet Detention Pond	Used for both quality and quantity control Drainage area of 10 acres to 1 sq mile Preferred BMP for nutrient removal	Moderate precipitation and low soil infiltration rates are required to maintain permanent pool Space constraints	Well designed ponds function as designed for 20 or more yr	Inspect structural integrity of embankment and inlet and outlet Erosion control Periodic sediment removal and algal/plant control	Average 25 to 40% more than conventional storm water detention Costs include wetland permits and dam safety certificates	Reduces downstream flooding and erosion Efficient removal of particulates, metals, and soluble nutrients
Sand Filter (underground)	Preferred over infiltration devices where ground water contamination or impermeable soils are a concern Suited for impervious sites	Limited to small drainage areas Potential for clogging May not function as well in cold climates	Increased by proper design and maintenance Replacement of filter media may be needed within 3 to 5 yr	Inspect after major storms Monitor dewatering times Replacement of clogged filter media	$6,300 to $10,500 for pre-cast filters for drainage areas <1 acre	Efficient removal of particulates, BOD, and coliform bacteria Low nutrient removal

Table 1. Summary of the factors affecting the selection of BMPs.

Applications

Water quality inlets can be used where sediments and free oil are a concern such as at vehicle maintenance facilities, loading areas, and parking lots. Filtration devices provide additional treatment for removal of pollutants associated with particulates, including metals, BOD, nutrients, and bacteria. Soluble organic compounds, nutrients, and metals can also be removed by an infiltration trench; however, its application is limited to small drainage areas and groundwater contamination is a concern. If sufficient land area is available, a wet detention pond can be designed to achieve pollutant removal that is comparable to an infiltration trench.

Limitations

Common limitations of the BMPs include the need to minimize the input of high loadings of sediments and hydrocarbons and a

decreased performance in cold environments. Each of the BMPs, except the wet detention pond, is limited to relatively small drainage areas (<10 acres) or should receive just a portion of the runoff, usually the first flush. Only wet detention ponds provide both quality and quantity control of storm water. However, land availability may be a concern for wet ponds.

Longevity and Maintenance

Routine maintenance is essential to effective, long-term BMP operation. Schueler (1992) found that poor pollutant removal in water quality inlets was related to a lack of regular clean-outs. Greater than 50 percent of infiltration trenches fail after five years because of poor design and clogging of the trench (Lindsey et al, 1991). These BMPs will function well beyond five years, if pretreatment BMPs or diversion structures are in place and clogged media is routinely replaced. Well designed and well maintained wet detention ponds continue to perform well after 20 years (Schueler et al, 1992).

Construction Costs

The cost of construction includes permits, excavation, BMP installation, landscaping, and, perhaps, the addition of pretreatment BMPs or diversion structures. Construction costs for water quality inlets, sand filters, and infiltration trenches are comparable [costs in Table 1 are based on 1989 dollars (SEWRPC, 1991)]. Pre-cast water quality inlets and sand filters are less costly than cast-in-place units. Wet detention ponds are considerably higher in cost; the size greatly influences the construction costs. Additional costs for wet pond installation may include wetland permits and dam safety certifications.

Environmental Impact

Downstream water quality is improved through pollutant removal. In addition, wet ponds reduce stream bank erosion and flooding by controlling the quantity of runoff released. This attribute is important in commercial areas and industrial parks where high runoff flows can damage stream habitat.

Potential adverse impacts to the environment should be minimized. Control measures include prevention of ground water contamination from infiltration trenches and proper disposal of sediments captured by the BMPs.

Summary

A variety of structural BMPs are available to control wet weather pollution at industrial facilities. The selection of an appropriate BMP should include a review and comparison of several factors, including performance, limitations, longevity, design criteria, maintenance requirements, costs, and environmental impacts. These criteria can also be used to evaluate newly developed

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Petroleum Hydrocarbon Concentrations Observed in Runoff From Discrete, Urbanized Automotive-Intensive Land Uses

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Introduction

This documents a portion of work performed by the Metropolitan Washington Council of Governments (MWCOG) for the State of Maryland Department of the Environment (MDE) and EPA's Chesapeake Bay Program Office (CBPO) pertaining to a comprehensive study of the generation and control of petroleum hydrocarbons in urban runoff. The purpose of this particular study task was to characterize the relative contribution of petroleum hydrocarbons and other typically encountered urban pollutants contained within stormwater runoff from small, single land use catchments. The following four automotive-intensive land uses were evaluated: (1) all-day parking lots, (2) streets, (3) gas stations, and (4) convenience commercial. The study was conducted from October, 1992 through December, 1993. The study area encompassed the District of Columbia and Suburban Prince George's County, Maryland.

Methodology

Due to budgetary constraints, only one site per land use was studied. The following prerequisite conditions were met for each site: (1) the selected site had to be representative of the general land use classification, (2) the selected site had to be uncontrolled from the perspective of stormwater management, (3) the selected site had to be feasible for discrete land use monitoring (e.g. all stormwater flows had to emanate exclusively from the targeted land use).

The study monitoring contractor, the Occoquan Watershed Monitoring Laboratory (OWML) suggested the use of Cashockton Wheel samplers due to their ability to sample a vertical "slice" of the influent stormwater

column. Due to the known partitioning of various petroleum hydrocarbon fractions in stormwater runoff, OWML felt the Cashockton Wheel samplers were superior to traditional automated samplers in obtaining a representative characterization of petroleum hydrocarbons from each site's runoff. They consist of a small "H" flume connected to a gravity-driven, rotating flow splitting device. As runoff flows from the impervious surface to the monitoring station, it is collected and funneled to the sampler by the "H" flume. The elevational differential between the flume and the horizontally-oriented platter-like wheel turns the wheel, via energy imparted to turning vanes from the falling inflow. As the wheel spins (similar to a record player), it splits a fraction, or "slice" of the stormwater inflow into a collection vessel through a small slot in its surface. This configuration yields a flow-weighted composite runoff sample and associated event mean concentrations (EMC) for each of the evaluated constituents. The Cashockton Wheels were deployed inside catch basins (3 sites) and within a locked fiberglass monitoring shed in a surface installation (1 site). Notable operation and maintenance constraints were encountered with the use of the Cashockton Wheel samplers in the study context. Urban grit and organics were found to impede the normal rotation of the samplers. For this reason, all samplers were temporarily removed from service and retrofitted with sealed, Teflon-coated central bearings. Even following retrofitting, the problem persisted, requiring close attention and frequent cleaning following storm events and regularly-scheduled weekly maintenance visits.

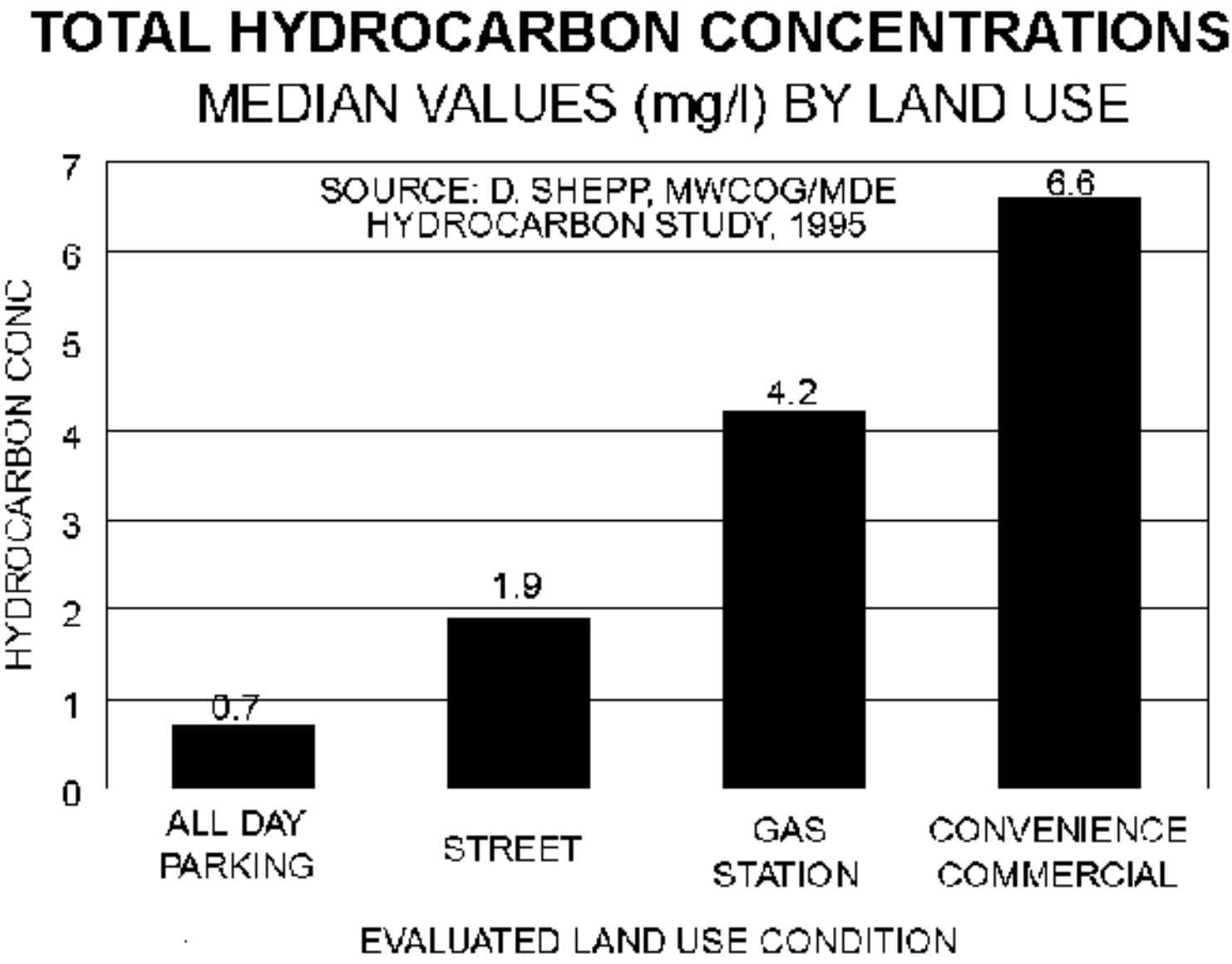
Rainfall measurements (rain depth) for 3 of the 4 sites were collected at the nearby USDA National Arboretum raingage. Due to the distance to the gas station site (located in Laurel, Maryland) an additional gage was installed on the stations' rooftop. Storm samples were retrieved following rainfall events and transported to OWML in Manassas, Virginia for laboratory analysis. A technique, utilizing non-dispersive infrared spectrometry, was developed for the purpose of evaluating the concentration of total hydrocarbons. OWML staff developed a functional relationship between petroleum hydrocarbon concentration and associated light transmittance in the infrared wavelength of 3.5 microns. It represents an improvement over standard gravimetric methods for oil and grease since it requires less lab time, reduced sample volumes and avoids "noise" from non-target solids in the sample volume. Associated limitations for this methodology include its lack of specificity (the results cannot be compared with results from studies which generate a higher degree of fractional resolution) and the potential for a lack of accounting for as much as 50% of the lighter fractions (due to their loss via volatilization during extraction); this can result in a conservative estimate of the total hydrocarbons. In a practical context, the total hydrocarbon concentration represents a changable, dynamic index where, due to field volatilization rates, the lighter fractions escape within a few days from the surface of the water column to the atmosphere.

Results

The following include the most important findings of the study:

1. While the total imperviousness for each site was virtually equivalent (estimated values ranged from 95-100%), the observed median EMC's for each site exhibited substantial differences (see Figure 1). The observed mean EMC's for each site exhibited a similar pattern as evidenced by arraying the studied land uses in descending order of total hydrocarbon concentration: (1) Convenience Commercial, mean observation: 12.4 milligrams per liter, range: 2.7 to 56.0 milligrams per liter, (2) Gas Station, mean observation 3.7 milligrams per liter, (3) Street, mean: 2.2 milligrams per liter, range: 0.8 to 4.7 milligrams per liter, and (4) All day Parking, mean: 0.9 milligrams per liter, range: 0.3 to 4.4

milligrams per liter.



2. Analysis of variance (ANOVA) indicated that significant differences exist between the observed means. Two-sample F-Tests of significance revealed that the majority of the means were significantly different from each other. Only the comparison of street and gas station means lacked sufficient significance to accept the null hypothesis. This suggests that imperviousness is not an acceptable singular indicator for predicting total hydrocarbon concentrations associated with automotive-intensive land use.

3. Data scatter plots revealed the following observed relationships:

    - Rainfall Depth vs. Total Hydrocarbons. The All day parking, Street and Convenience commercial sites exhibited a negative relationship, whereas the gas station site exhibited a positive relationship.

    - Rainfall Depth vs Total Suspended Solids. The All day parking, Gas Station and Convenience commercial sites exhibited a negative relationship, whereas the Street site exhibited a positive

relationship.

- Total Hydrocarbons vs Total Suspended Solids. All sites exhibited a positive relationship.

4. Observed data suggests a relationship between automotive exposure and total hydrocarbon concentration. Thermal expansion and contraction of oil-bearing regions of automotive drive trains is thought to be the primary source of petroleum hydrocarbons, via seepage. Duration of automotive exposure (i.e. the time a given impervious surface is exposed to hot vehicles in a thermal expansion mode) as well as volume of automotive exposure (i.e. the number of hot vehicles in a thermal expansion mode exposed to a given impervious surface) are suggested as the principal factors in the generation of petroleum hydrocarbon pollution upon automotive intensive land uses (see Table 1).

Table 1. Automotive Exposure and Observed Hydrocarbon Concentraions by Land Use.

Land Use	**Duration of Automotive Exposure**	**Volume of Automotive Exposure**	**Observed Median Conc.**
ALL DAY PARKING *National Arboretum*	LONG (4 to 8 Hours per Car per Day)	LOW (1 to 2 Cars per Parking Space per Day)	0.7 mg/l
GAS STATION *Laurel Texaco*	MODERATE (5 to 10 Minutes per Car per Day**No Repair/Maint. Service Provided**Pump & Pour Your Own "Micro Spills" Anticipated)	MODERATE (A Steady Stream of Cars Throughout Day)	4.2 mg/l
STREET *20th @ Franklin St.*	BRIEF (10 to 60 Seconds, Depending on the Traffic Light Cycle)	HIGH (1,000 plus Cars Estimated; AM & PM Rush Hr. Peaks, Steady Midday Use as Secondary Roadway)	1.9 mg/l
CONVENIENCE COMM. *N.h. Ave. Mcdonald's*	MODERATE (10 to 30 Minutes per Car per Day Estimated)	MODERATE/HIGH (Breakfast, Lunch & Dinner Peaks, Steady Throughout Day)	6.6 mg/l

5. Many of the highest observed concentrations were associated with rainfall depths less than 0.25 inch,

with accompanying durations spanning 2 to 3 days. Concentrations associated with such low volume, low intensity events clearly underscore the relative ease of mobilization of petroleum hydrocarbons from impervious surfaces. Examination of rainfall patterns in the middle Atlantic region show that on average, (approximately every 3 to 4 days) precipitation events, with the potential to mobilize surprisingly high concentrations of petroleum hydrocarbons, occur. Furthermore, given their relative ease of mobilization, the potential for the delivery of substantial concentrations of petroleum hydrocarbons from automotive-intensive land uses to receiving waters exists both regionally and nationally for the majority of measurable annual rainfall events. The observed data suggest the principal source (automotive), its associated accumulation medium (imperviousness) and delivery mechanism (normal rainfall) central to this cycle.

6. Two separate items of information serve to provide a useful context for understanding the importance of the observed median total hydrocarbon concentrations presented in Figure 1 and the previously-mentioned range of observed concentrations for each land use (i.e. 0.3 to 2.4 milligrams per liter for the All day parking site, 0.8 to 4.7 milligrams per liter for the Street site, 1.2 to 5.5 milligrams per liter for the Gas station site, and 2.7 to 56.0 milligrams per liter for the Convenience Commercial site). First, maximum concentrations observed from the Convenience commercial site, 56.0 milligrams per liter, exceeded recently monitored observations for Hickey Run in the District of Columbia (50.0 milligrams per liter). Hickey Run has the dubious distinction as the most polluted subwatershed in the degraded Anacostia Watershed (due primarily to a history of chronic and episodic waste oil dumping) and as one of the most polluted urban subwatersheds in the entire Chesapeake Bay drainage. Secondly, recommended maximum concentrations of petroleum hydrocarbons for drinking water supplies and fisheries protection typically range from 0.01 to 0.1 milligrams per liter; crude oil concentrations of 0.3 milligrams per liter can cause toxic effects in freshwater fish (D. Chapman and V. Kimstach, 1992).

7. Evaluation of rank and percentile of observed rainfall and hydrocarbon concentrations occuring over the span of an entire year indicated that 23 of 30 (or 77%) of the top half, or highest, observed total hydrocarbon concentrations could be managed via effective stormwater controls designed to treat the first 0.5 inch of runoff from the studied sites. If a 0.25 inch design treatment volume was utilized, 12 of 30 (or 40%) of the top half of the highest observed concentrations could be managed. These values stand in stark contrast when compared to the currently prevailing design rules for target treatment volumes relative to the control of petroleum hydrocarbons in urban runoff. Typical oil-grit separator design is based upon a 0.10 inch treatment volume of runoff. Utilizing the same overall dataset, this level of control equates to treating 2 of 30 (or 7%) of the highest hydrocarbon generating events of the evaluated annual rainfall.

Implications

Based upon analysis of the study observations, the following conclusions were reached:

1. Evaluation of the observations suggest that runoff concentrations of petroleum hydrocarbons from automotive-intensive land uses typically range from 0.7 to 6.6 milligrams per liter. Given the recommended maximum petroleum hydrocarbon concentrations of petroleum hydrocarbons for

drinking water supply and fisheries protection (0.01 to 0.1 milligrams per liter) and the reported toxic effects observed in freshwater fish from crude oil concentrations of 0.3 milligrams per liter (D. Chapman and V. Kimstach, 1992), the observed total hydrocarbon concentrations suggest their substantial national impact as a nonpoint source pollutant. This suggestion is futher reinforced by the knowledge that many of the monitored automotive-intenstive land uses are commonly found throughout all, but the most rural and remote areas, of the United States.

2. Evaluation of the observations and their respective catchment areas suggest that the degree of automotive exposure (a combination of duration of exposure and volume of exposure) is the primary factor in the generation of petroleum hydrocarbons in runoff from automotive-intensive land uses. The pollutant pathway: (1) originates via drive train seepage from automotive vehicles, (2) accumulates upon highly impervious surfaces designed for automotive conveyance or parking, and (3) is readily mobilized via runoff produced by low volume, low intensity storms. The measured and visual observations gathered throughout the course of the study suggested, with the notable exception of expensive, new cars (W. Bell, et.al., 1995), virtually all motorized vehicles seep a measurable volume of petroleum hydrocarbon based lubricating agents. Casual visual observation suggests a wide range in the relative rates of seepage exists from vehicle-to-vehicle. Further visual observation suggests this variability is primarily a function of the age and relative degree of mechanical upkeep associated with a given vehicle.

3. Application of BMP's effective in the control of petroleum hydrocarbons is suggested for the treatment of runoff from automotive-intensive catchments as small as 0.5 acres. Recent performance evaluations of sand filtration BMP's , independently conducted by the District of Columbia (H. Troung, et. al.,1993) and the City of Alexandria, Virginia (W. Bell , et.al., 1995), suggest removal efficiencies for total hydrocarbons in excess of 77 per-cent. In addition to their reported removal efficiencies, the local availability of sand and gravel resources in the Middle Atlantic's Coastal Plain enhances the attractiveness of filtration-based treatment of runoff from automotive-intensive land uses. Design treatment storage volumes up to the first 0.5 inch of runoff are suggested for the treatment of petroleum hydrocarbons in the Middle Atlantic region.

4. A seepage evaluation is suggested as a new pollution prevention component of regularly-scheduled vehicular safety/emissions inspections. A simple, relatively "low tech" approach could be developed, possibly using kraft paper as an evaluation medium. The diameter and number of seepage stains accumulated over a pre-determined evaluation period could potentially be utilized to develop an evaluation metric for identifying unacceptably high petroleum hydrocarbon seepage rates. A possible hierarchy of corrective actions could include: (1) mechanical tightening of drive train mating surfaces containing petroleum hydrocarbon lubricants, (2) the external application of petroleum hydrocarbon and heat resistant flexible sealants to seeping areas and (3) replacement of deteriorated and/or hardened gaskets and seals (this represents the last choice due to its associated disassembly time and related expense). An accompanying public education/outreach initiative as an additional component of a comprehensive pollution prevention program is suggested. The effort could be specifically targeted for the general public and the automotive repair and service industry. Its focus could revolve around the need to raise the public's awareness of the ubiquitous nature and potential environmental damage associated with uncontrolled/untreated petroleum hydrocarbons in runoff from automotive-intensive land uses.

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Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

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Environmentally Sensitive Low-Impact Development

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Introduction

Urban development has proven to greatly alter the quantity and quality of receiving water resulting in cumulative impacts on the physical, chemical, and biological integrity of ecosystems (Galli, 1992). Urbanization has been associated with significant degradation of aquatic, riparian, and terrestrial habitat through loss of ecosystem quality and connectivity; loss of wildlife corridors; increases in the intensity, frequency, duration, and transport capacity of the hydrologic regime; and increases in pollutant buildup. Zoning and site planning requirements reduce impacts by preserving sensitive areas such as wetland and floodplains. However, developed areas continue to exhibit significant disturbances due to massive grading. Several structural management measures, derived mostly from flood control practices with little or no adaptation, have been implemented to control the environmental impact of new development or to retrofit existing facilities. Although in a few situations such measures have been demonstrated to control certain types of pollutants, they have been of limited value in comprehensively addressing ecosystem integrity. Furthermore, implementation of such measures has led to the development of programmatic and engineering practices that pose various roadblocks to engineering and scientific creativity and innovation in the way sites are developed. It is now well understood that controlling urban development after the fact is expensive. Conventional measures are costly to implement and to maintain while they achieve only limited ecological balance. There is therefore, a growing need to reevaluate current practices in all phases

of urban development to incorporate innovative, cost-effective management measures.

The Prince George's County, Maryland, Low-Impact Development (PGLID) approach presents a new perspective in urban development. It integrates site ecological and environmental requirements into all phases of urban planning and design, and it considers the implications of development on a broad scale ranging from the watershed to the individual residential lot. This comprehensive approach relies on balancing urban development impacts and site design features while enhancing lot yields, reducing development costs, and encouraging development and economic growth. The goal of developing such an environmentally sensitive approach is to eliminate, minimize, or mitigate the "root" causes of development-generated impacts at the sources. This goal is achieved through the harmonious integration of site fingerprinting that preserves sensitive habitat and its connectivity and stormwater management measures that make the development's landscape more ecologically and hydrologically functional. This paper describes the concepts used to develop PGLID and the benefits to the developer, property owner, and county. The Prince George's County has implemented this approach on a 200-acre residential subdivision called Somerset, in cooperation with a developer and with significant contributions from the State of Maryland Department of the Environment and a number of federal agencies.

Objectives of Low-impact Development

The basic objectives of the PGLID approach include (1) restoring the site hydrologic regime to mimic the natural or predevelopment condition, (2) maintaining surfacewater and groundwater quality and minimizing the generation and off-site transport of pollutants, (3) minimizing disturbance of riparian habitat functions, and (4) preserving terrestrial habitat ecological functions and maximizing conservation of woodland and vegetative cover.

Mimic Hydrologic Regime. Typically, when developing a well-vegetated site such as a forested area into a residential community, several activities disturb the original site hydrologic response. Such activities include clearing and eliminating the original tree cover, piping and channelizing flow to minimize the risk of localized flooding, and compacting land surfaces and increasing impervious areas. This disturbance results in a higher runoff volume due to the loss of interception, infiltration, and depression storage; higher peak discharge and flow velocities due to increased imperviousness and runoff concentration and decreased travel time; increase of frequency and overall duration of higher flows due to the combined effects of increased runoff coefficients and flow routing and transport patterns; and decrease of baseflow and groundwater recharge due to higher imperviousness. Additional impacts include increased downstream flooding potential, accelerated erosion and stream physical and morphological instability, and increased water temperature. Consequently, significant degradation of stream biological integrity is often observed.

The Somerset development was originally planned using traditional development practices. Stormwater impacts were to be "controlled" by conveying stormwater runoff off lots and roadways through underground storm drain piping, and controlling peak discharge via three on-site wet detention ponds. Past experience with these facilities, however, pointed to their inherent environmental and economic

limitations and liabilities. The design and computation practices used to conceptualize such facilities still rely on traditional hydrologic flood control approaches, limiting their overall function in mitigating multiple and cumulative impacts. In addition, they are expensive to install and maintain. Through an aggressive public outreach program and effective coordination with various stakeholders, the plan for Somerset was redesigned based on the PGLID concept of restoring the site hydrologic regime to mimic the predevelopment condition. This concept was implemented through an integrated site design that reduces, eliminates, or treats the impacts at the source and attempts to restore the original hydrologic functions. Several landscape and on-lot control features considered (Box 1) are easy to construct and require little infrastructure maintenance, in addition to providing ecologically sustainable and balanced coexistence between residential users and the surrounding environment. In addition to the well-accepted aesthetic value, the on-site integration of such functional hydrologic features was implemented to compensate for each disturbance to the predevelopment condition and preserve the characteristics of various storm hydrographs. Measurable environmental benefits are anticipated from this environmentally sensitive landscaping application. Prince George's County has initiated a hydrologic, physical, biological, and water quality monitoring program to assess the "before" and "after" conditions. The county is also reviewing the strengths and limitations of available assessment tools and is developing design guidance and modeling techniques that could potentially assist both developers and the county's plan reviewers.

Box 1 **Hydrologic Design Features Considered**
On-lot storage and infiltration system
Functional landscaping
Open drainage swales
Reduced imperviousness
Flatter grades
Increased runoff travel time
Enhanced infiltration and depression storage
Minimized woodland disturbance
Runoff water conservation and reuse

Maintain Surface Water and Groundwater Quality. When developing a residential community, surface water and groundwater quality is typically impacted through both (1) hydrologic changes that increase erosion processes and pollutant transport capacity and (2) increased loadings of several pollutants associated with residential activities such as lawn care practices and car care practices, as well as impacts due to automobile and traffic activities, degradation of roads and building material, and atmospheric deposition. Water quality impacts are due not only to increases of conventional pollutants and nutrient loading but also to a major shift in the water quality composition. Significant increases in heavy metals, oil and grease, pest control chemicals, and other toxic organics, in addition to increases in bacterial counts and temperature are key characteristics of urban runoff (PGDER, 1993). To maintain surface water and groundwater quality and minimize the buildup and off-site transport of pollutants in Somerset, several functional landscape controls were considered (Box 2). On-lot integration of such features results in reestablishing and even increasing the surface storage capacity of the site; compensating for loss of infiltration due to increased imperviousness; and treating runoff through sedimentation, filtration, soil adsorption, microbial decay, and plant uptake. Bioretention, a key component of PGLID, provides multiple functions for hydrologic and water quality control using a micro-scale landscaped islands interspersed throughout each lot and the community. An active public participation program to promote pollution prevention practices and ensure proper maintenance of the functional role of landscape features was initiated by the county at the early phases of the development

and is being carried out by the county, developer, builder, home owners association (HOA), and individual residents. To facilitate this effort, PGLID homeowner brochures and landscaping and maintenance manuals have been developed by the county and distributed to all prospective home buyers. HOA covenants include provisions for the formation of an environmental committee to sustain PGLID pollution prevention and landscape maintenance efforts. In addition, individual homeowners are required to sign a bioretention area maintenance agreement to ensure participation in the community programs.

Box 2 **Water Quality Features Considered**
On-lot functional landscaping (bioretention)
Storage/Infiltration
Filtration/Removal
Grassed swales
Flow attenuation
Storage/Infiltration/Sedimentation
Reduced soil compaction and imperviousness
Sheet flow/Infiltration
Runoff water Conservation and reuse
Flow volume and concentration
Public education
Pollution prevention
Maintenance of functional uses

Riparian and Terrestrial Habitat Protection and Woodland Conservation. The biological integrity of a riparian system depends on maintaining the stability and balance of the watershed's dynamics, and its physical, chemical, and biological characteristics and processes over time. Conventional site planning techniques consider delineation of ecologically sensitive areas. However, developed areas are typically mass graded and then reconstructed, requiring the mitigation effort to be directed towards restoration rather than prevention. Basic approaches used in land development include the preservation of riparian corridors through wetland, floodplain, and buffer regulations (MOP, 1995). In addition, innovative control of hydrologic changes is also a key feature for effective preservation of the terrestrial habitat ecological functions and conservation of woodland and vegetative cover. The Somerset development uses the prevention of hydrologic changes, coupled with minimized grading and maximized stream riparian buffer setbacks, while allowing development to occur. The key functional landscape and control features considered in meeting the objective of PGLID for the preservation of riparian and terrestrial habitat are presented in Box 3.

Terrestrial habitat protection and woodland conservation also rely on the county's existing Woodland

Conservation and Tree Preservation programs. These existing regulatory programs provide an example of modifying zoning and subdivision ordinances and grading requirements to allow the flexibility needed to develop land with minimal impacts on terrestrial habitat. The Low-Impact Development approach expands the overall limits on woodland impacts in floodplains, in wetlands, and on steep slopes to include provisions for woodland connectivity and habitat, hydrologic, and water quality functions. Additional features considered in the Somerset site layout include the use of multifunctional backyard habitat, landscaped open space providing connectivity and habitat edge, and clustering developed areas. Other features under consideration include the use of smaller lots in cluster development, zero lot line subdivision design, use of common driveways to minimize pavement, integration of lot design into the existing woodlands landscape, site fingerprinting to reduce grading and disturbance, and xeriscaping.

Box 3 **Habitat Protection**
Riparian Habitat Protection
Mimic predevelopment hydrograph
Maintain baseflow and infiltration
Stream buffer protection and corridors
Wetland buffer protection
Floodplain buffer protection
Steep slope protection
Terrestrial Habitat Protection
Smaller lots and cluster development
Zero lot line subdivision design
Common driveways
Integration of existing woodlands landscape
Site fingerprinting
Addition of and enhancement of edge habitat
Woodland conservation and tree preservation
Xeriscaping

Flexible and Integrated Land Development Regulations

Generally, site designers and regulators examine the environmental mitigation requirements of a development in a mechanical fashion. Floodplains, natural resources, utilities, roadways, and the stormwater infrastructure are designed to meet "by the numbers" regulations. Site development designs and stormwater BMPs are usually selected based on subjective economic concerns, site constraints, jurisdictional preferences, personal preferences, and restrictive zoning. It is assumed that if one complies with a specific regulation, the adverse effects of development are adequately mitigated. Limited attention has been paid to maintaining predevelopment ecological functions to protect riparian integrity.

The Somerset development required both flexibility and coordination in regulatory review and enforcement. All components, including infrastructure, stormwater management, woodland conservation, and zoning were considered as an integrated package. This has allowed the county to work toward introducing and encouraging creative and cost-effective management alternatives. The regulatory review and consensus building have involved coordination among eight county review agencies, the Maryland Department of the Environment and federal agencies, and numerous public advisory and activist groups. Although the initial process was time-consuming, the development review process has been streamlined and is anticipated to provide for a more environmentally sensitive and sustainable community.

Cost savings

Changing the stormwater management approach from a "collect and treat/pipe and pond" strategy to the low-impact approach has significantly reduced site development costs. Cost savings are achieved as a result of less clearing; less earth work; less pipe; fewer drainage control structures; minimum use of roadside curb and gutter; less road pavement; fewer sidewalks; and lower wetland, tree and stream mitigation costs. The developer's benefits included in addition to a significant savings in infrastructure construction and a successful market acceptance. This approach has also resulted in reduced local government BMP maintenance costs and a potential savings to residents through tax reduction.

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