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### Toward Ecologically Sustainable Water Management: The Roles of Science and Technology

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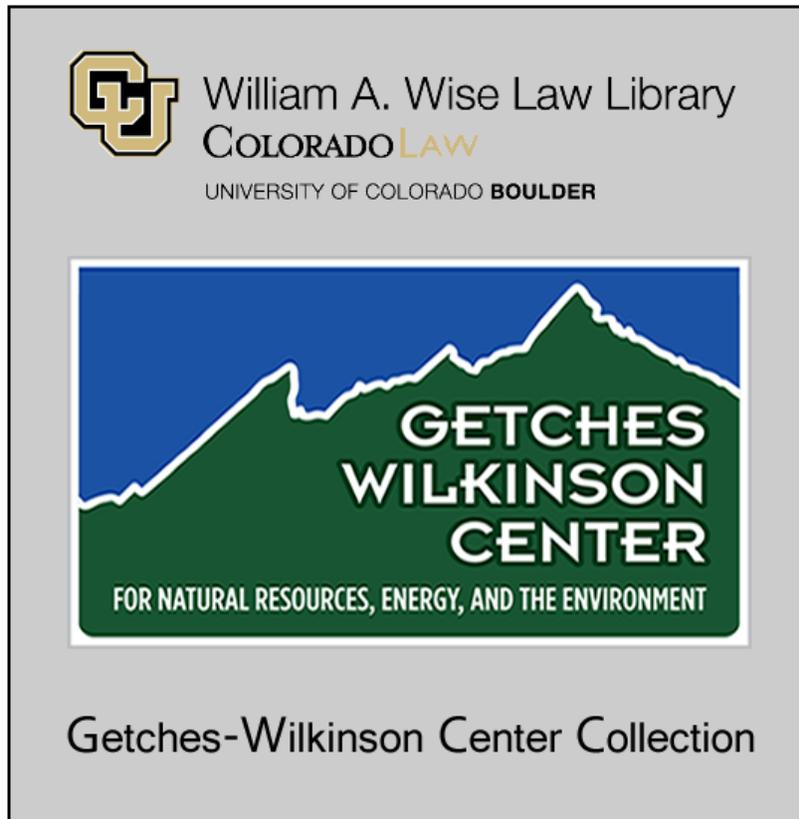
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**TOWARD ECOLOGICALLY SUSTAINABLE WATER MANAGEMENT:  
THE ROLES OF SCIENCE AND TECHNOLOGY**

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*Two Decades of Water Law and Policy Reform:  
A Retrospective and Agenda for the Future*

June 13-15, 2001

NATURAL RESOURCES LAW CENTER  
University of Colorado  
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Boulder, Colorado  
**Toward Ecologically Sustainable Water Management:  
The Roles of Science and Technology**

**by Brian Richter**

## I. Summary

As the world's population continues to grow along with associated increases in water use, social planners and governmental leaders are exploring strategies for managing water resources sustainably. This quest centers on managing human uses of water such that enough water of sufficient quality is available for use by future generations.

These same fresh water resources – rivers, streams, lakes and aquifers – support abundant and specialized forms of biodiversity. However, in the struggle to manage water to meet various human needs, the water needs of freshwater species and ecosystems have been largely neglected. As a result, a large proportion of aquatic animal groups such as freshwater fish, mussels, crayfish, and insects have become imperiled.

Natural freshwater ecosystems also provide innumerable services and products valued by society, ranging from waste dilution and ground water recharge functions to the provision of timber and fish for human consumption. These natural values are estimated to exceed \$9 trillion per year globally. Any retrospective analysis of the ecological consequences of water management during past decades would have to conclude that we have been killing a goose that lays golden eggs – one of the disastrous consequences of traditional water management has been a substantial loss of these natural freshwater ecosystem benefits. If future visions of “sustainable water management” do not explicitly address the water needs of both humans and freshwater ecosystems simultaneously, the trend in our quality of life will continue to slide toward impoverishment rather than sustainability. This does not need to be our destiny. During the past decade, many case studies have emerged from around the world demonstrating ways of meeting human needs while sustaining the necessary volume and timing of water flows to support affected freshwater ecosystems. Our freshwater group in The Nature Conservancy has offered this touchstone for efforts in “*ecologically sustainable water management*”:

*Ecologically sustainable water management protects the ecological integrity of affected ecosystems while meeting inter-generational human needs for water and sustaining the full array of other products and services provided by natural freshwater ecosystems. Ecological integrity is maintained when all existing*

*native species and the natural productive capacity of the freshwater ecosystems are sustained.*

Successful attainment of ecologically sustainable water management will require key contributions from many sectors of society, including policy leaders that will need to shape future approaches to water management and managers that can facilitate the balancing act that sustains both humans and ecosystems. This balancing act must be informed by the best possible science, and it must be supported by the best available technology.

One of the most urgent and important challenges confronting today's scientists is the need to guide resource managers toward ways of extracting what humans need while leaving in place those ecological conditions necessary to sustain ecosystem health. With respect to water management, this means aligning the timing and volume of human manipulations of water supplies with the (water) flow regime characteristics necessary for sustaining healthy freshwater ecosystems. This will require assembling the knowledge and judgement of inter-disciplinary scientists (e.g., hydrologists, geomorphologists, biologists) to interpret the water needs of freshwater species and the role of water flow in supporting the proper functioning of whole freshwater ecosystems.

But even the very best team of scientists will not likely "get it right" on the first try in a specific place – the life histories of species are too varied, and the inner workings of ecosystems too complex, to know with great confidence. Thus, ecologically sustainable water management will require careful design of, and adequate investment in, adaptive water management programs that enable learning over time through research and monitoring. The scientists may not get it right on the first try, but they will do better if given the opportunity to learn.

Ecologically sustainable water management will also benefit greatly from more extensive and regular use of currently available computer technologies. Computerized simulation models are now being used to reveal the complex spatial and temporal dynamics of entire ecological and hydrological systems, and to assess their likely trajectories under

alternative water management scenarios. These tools can help ecologists make better predictions of the ecosystem outcomes to be expected under various water management scenarios. They can also help water managers understand how they might best store and extract water for human uses while leaving in place ecologically compatible water flow regimes.

Technological tools such as “decision support systems” can also be used to foster greater understanding among all stakeholders, thereby increasing the probabilities for developing consensus about water management plans. Decision support systems are simply software packages that facilitate the management and display of data and computer-based tools – a virtual “commons” that provides access to information and ways of analyzing that information. At the very least, making a decision support system available to all parties can help focus discussions about the information needed to inform water decision-making. When used to their full potential, the analyses and graphical renderings that can be produced using decision support systems can help illuminate pathways toward ecologically sustainable water management.

## **II. A Framework for Ecologically Sustainable Water Management**

- A. The Nature Conservancy has suggested a general framework for ecologically sustainable water management, consisting of six basic steps that should be performed iteratively.
  1. Define ecosystem flow requirements
  2. Determine influence of human activities
  3. Identify areas of potential incompatibility
  4. Foster collaborative dialogue
  5. Conduct water management experiments to resolve uncertainty
  6. Design & implement an adaptive management plan

## **III. The Role of Science in Defining Ecosystem Flows**

- A. Scientific community has galvanized around the importance of natural flow regimes for conserving freshwater biodiversity

1. Because humans need to use the same water resources, we need to understand the degree to which natural flow characteristics can be altered for human purposes while continuing to support ecological integrity
- B. Scientists are increasingly using computerized simulation models to understand complex workings of systems
  1. Hydrological simulation models can be used to understand the interactive and cumulative effects of human water uses throughout a watershed to gain understand of their net influence on natural flow regimes
  2. Ecological simulation models are helping scientists understand how inter-related hydrologic and ecological dynamics play out over long time frames
- C. In the face of considerable uncertainty, scientists are increasingly using interdisciplinary expert workshops to build consensus recommendations for ecosystem flow requirements.
- D. Ecological and hydrological (as well as social and economic) uncertainties can paralyze efforts to practice ecologically sustainable water management. By designing water management experiments to resolve critical uncertainties, stakeholders can continue to collaborate while uncertainties are reduced to manageable and tolerable levels.

#### **IV. Using Technology to Support Water Decision-Making and Planning**

- A. Decision support systems provide a “virtual commons” in which common data is made available to all parties, thereby fostering transparency
- B. Decision support systems might also include analytical tools that enable rapid evaluation of alternative scenarios for water management. The results might describe hydrologic or ecological conditions over time, at various locations within the watershed. If these results are displayed in means (e.g., graphically) that are readily understandable by affected and interested parties, the decision support system can become a powerful tool for facilitating broad understanding of management alternatives and help lead to consensus.