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Water Resources Sustainability: A Guide to This Issue

Ethan Timothy Smith* and Christopher Lant**

**Sustainable Water Resources Roundtable and **Southern Illinois University Carbondale*

This issue of *Water Resources Update* includes a variety of papers about water resources sustainability in the United States. Though terms like "sustainability" come and go over the years, they have a foundation in truth. Wary of making a claim on the philosopher's stone, we have opted to approach the problem of "sustainability" in the spirit of research. To do so, we have provided a number of views that have elements that agree and disagree with one another. We hope that we can facilitate a dialogue that will lead to a consensus on how the broad concepts of sustainability apply to the essentially pragmatic problems of water resources management.

The Future Imperative

Institutions develop over decades and centuries to fulfill specific essential social needs. Of course, water resources management is no exception to this rule. As social needs change, however, institutions are sometimes slow to adapt. In water resources, our institutional arrangements are designed for the social needs of the past century: capturing water and delivering it for public health and economic uses; engineering rivers to facilitate navigation, generate electricity, and minimize flood losses; and treating urban and industrial wastewater. Civil and environmental engineering, hydrology, administrative law and economics as applied to the evaluation of public investments have provided the primary intellectual foundation upon which these essential water-based needs have been met. While our institutions have served us well, they are pressed to cope with a future in which water quality and availability for rapidly changing demands, ecological health of fresh and coastal waters, integrative use of surface and ground water, and land use patterns must be considered simultaneously in geographical settings of watersheds. This great variety of water resources topics must also be placed in the context of national priorities such as public health and safety, economic performance, and foreign policy, and their consideration must take place within the cultural and political framework within which Americans do their work.

The Sustainable Water Resources Roundtable

The Sustainable Water Resources Roundtable (SWRR) was created under the Advisory Committee on Water Information to promote the exchange of information among representatives of government and industry, as well as environmental, professional, public interest, and academic groups. It began in 2001 with the help of Dr. Ethan (Tim) Smith of the U.S. Geological Survey. And in the three years since its inception, Tim's efforts have brought hundreds of people together to discuss water resources sustainability. The result is a tribute to his skills as a coordinator and motivator of people. Without his efforts, neither the Roundtable nor this issue would have been possible.

SWRR is intended to provide a venue for those persons who wish to examine some aspect of the

many interrelationships noted above or their future implications for the nation. Information about SWRR is available at http://water.usgs.gov/wicp/acwi/swrr/. Readers interested in participating in discussions aimed at defining and applying the concept of water resources sustainability are encouraged to contact the SWRR.

Conceptualizing, Measuring, and Implementing Water Resources Sustainability

The challenges in addressing such a broad and potentially ambiguous topic as this are great and require a conceptual strategy. The strategy we have chosen is to focus on three overriding questions:

(1) What does water resources sustainability mean?
(2) How can it by measured?
(3) How can it be implemented?

This introductory paper will focus on these three questions and serve as a guide to the issue as whole.

Water Resources Sustainability: What Does it Mean?

In the first paper of this issue, Theodore (Ted) Heintz of the White House Council on Environmental Quality lends his eloquent voice to "defining the concept of sustainability to water resources management." Like other authors in this volume, Heintz focuses on the maintenance of capital—natural, economic and human—as the key to understanding the concept of sustainability. However, Heintz also borrows from Fritjof Capra and other complexity theorists as he focuses on the critical role of "feedback" in achieving sustainability. Just as life has been *sustained* on Earth for three billion years through feedback mechanisms within organisms, among organisms and their environments, and between the biosphere and the planet, so water resources sustainability relies on the strengthening of feedback loops. The most important of these feedback loops answers the question "How are we doing?", and it is strengthened by *measuring* how we are doing and bringing the indicators derived from these measurements to bear in making water resources management decisions. Sustainable development is therefore achieved through *adaptive management*.

Rhonda Kranz of the Ecological Society of America leads SWRR's conceptual development team and offers their paper on the "conceptual foundations for the Sustainable Water Resources Roundtable." To Heintz's ideas on capital and feedback, Kranz et al. add and integrate concepts from information theory. For example, they write about how the Information Pyramid is built upon detailed measurements from which are gleaned specific indicators that are used to evaluate the achievement of criteria that are, in turn, summarized as stories. At each step in this hierarchy, information is condensed into fewer and fewer pieces of information of greater and greater meaning. According to Kranz et al. the process of gathering and using information to achieve sustainability in water resources management is also similar to that in treating a medical patient, where tests are conducted to provide feedback on the state of the patient's physiological systems in order to "diagnose" their problems, form a "prognosis" of their future conditions and determine a course of action to improve those forecast conditions. Additional feedback is then acquired to determine the effects of actions taken. In this way, informational feedbacks guide us progressively toward the capital maintenance goals of sustainability.

Chris Lant, Executive Director of UCOWR at Southern Illinois University Carbondale, defines water resources sustainability from an ecological economics perspective. To the capital and systems approach used in the previous two papers, Lant adds the concept of intellectual capital, the distinction between human and social capital, and addresses the role of the market economy in transforming natural, human, manufactured and intellectual capital, one into the other, as guided by the institutional rules incorporated as social capital. Within this framework, "weak" sustainability (the maintenance of total capital value) can be distinguished from "strong" sustainability (the maintenance of value of each type of capital). The role of water in contributing to each of these forms of capital and as the key component in the production of ecosystem services is explored in the contexts of a human right to water, IWRM, and "virtual" water.

Stephen Gasteyer of Rural Community Assistance Partnership investigates the role that social capital at the community scale plays in achieving sustainable water resources management.

For example, small communities can seldom afford anti-terrorist technologies such as retina identification to guard their water supplies, but may be better served by strengthening community ties to prevent routine vandalism. At a larger scale, maintaining sustainable practices in land and water management by building synergies between social and natural capital can serve security needs effectively. Building social networks of trust and mutually beneficial interdependence is therefore the social infrastructure of water resource sustainability.

Warren Flint of Five E's Unlimited also defines sustainability in systems terms, especially with respect to interactions among economic, social, and environmental sub-systems, all of which command forms of capital that are critical to sustainability at the scale of human communities. Flint identifies a number of "unsustainable" conditions where reform is required if sustainability is to be achieved. These conditions include the continuing unnecessary suffering and loss of human life due to lack of access to safe drinking water in several regions of the developing world as well as the need to value natural capital (in national income accounting and other politically potent ways) for it's waste absorption and ecological maintenance capacity as well as its capacity for natural resource regeneration.

Jill Baron of USGS and N. LeRoy Poff of Colorado State University provide a strong conceptual foundation for understanding natural capital and ecosystem services in the context of "sustaining healthy freshwater ecosystems." The health of "disproportionately rich and disproportionately imperiled" freshwater ecosystems of North America is based in their natural complexity and adaptive capacity. These characteristics are derived in turn from flow patterns, sediment and organic matter inputs, temperature and light characteristics, nutrient and other chemical conditions, and plant and animal assemblages, all of which are objective and measurable, but interdependent, environmental factors. According to Baron and Poff, the maintenance of freshwater ecosystem health can be greatly improved by (1) incorporating natural flow patterns and maintaining ecologically necessary in-stream flows in water allocation decisions, (2) managing at the watershed scale, (3) taking an inter-disciplinary approach, (4) increasing restoration efforts, and (5) maintaining and protecting freshwater ecosystems that are currently healthy.

Water Resources Sustainability: How Is It Measured?

Tim Smith provides an introduction that serves to bring to bear the efforts of other resource-oriented roundtables, such as forestry, rangelands, and minerals, on the problem of measuring water resources sustainability through the use of indicators. By doing so, the water resource community need not "reinvent the wheel" and can gain considerable consistency with the other Roundtables. Smith also raises fundamental issues about development of indicators such as balancing comprehensiveness with simplicity, identifying the appropriate spatial and temporal scale, and prioritizing indicators to reflect critical issues. Perhaps most challenging is the dilemma of measuring indicators at fixed points in time to reflect a system that is inherently dynamic and, as discussed by Ted Heintz, "complex."

Kent Cavendar-Bares and Robin O'Malley of the H. John Heinz Center for Science, Economics and the Environment bring to bear the fruits of their great undertaking in measuring *The State of the Nation's Ecosystems*. While their important document is a "neutral assessment" of several forms of natural capital, it provides a model and the empirical basis for an evaluation of sustainability that goes far in accomplishing the measurement task of the Roundtable. The Heinz approach is to focus on system dimensions, chemical and physical conditions, biological components, and human use. While utilizing a broad array of existing data in their assessment, products of over one-half billion dollars per year in environmental monitoring and related research, they also identify critical data gaps and assess the priority for filling these gaps. The Heinz Center is well ahead of the curve in evaluating natural capital, and their work could be used as a model for other similar endeavors.

Paul Barlow, William Alley and Donna Myers of the U.S.G.S focus on the measurement of sustainability using the hydrological cycle as a guidepost. Their work places particular emphasis on the long term and the importance of spatial scale. Here again, critical gaps in data lead to critical gaps in knowledge, which lead, in turn, to difficulties in assessing sustainability. Because the state of ground water in the Unites States is poorly understood and because there is also a poor quantitative understanding of water use, the improvement of the

knowledge base in these two areas is key for U.S.G.S. data collection efforts.

Water Resources Sustainability: Critical Implementation Issues

Joe Dellapenna of Villanova University School of Law launches the implementation section by asking "is sustainable development a serviceable legal standard in the management of water?" Sustainable development has considerable political standing internationally as expressed in the *Stockholm Declaration* and other venues. However, to be legally effective it must take form as a criterion of policy choice. Should this criterion be "sustainable development," "sustainability," or "sustainable use"? In each case, determining whether the criterion is met is highly dependent on case-specific facts. Like budget-balancing, sustainable use cannot be an absolute obligation even when it is good practice under normal circumstances to balance the needs of present and future generations. Dellapenna concludes that sustainable development "prescribes a process of analysis and decision making rather than a strict legal standard for resource use."

Sujoy Roy and Karen Summers of Tetra Tech and Robert Goldstein of the Electric Power Research Institute analyze future water availability at the county level and provide some very useful maps of their water supply sustainability index and thermoelectric cooling water supply limitation index. Even though national water withdrawals have ceased to grow since 1980, population increase will lead to the intensification of local water shortages, especially for use in the domestic supply and thermoelectric cooling sectors. Water availability will continue to place limitations on the location of fossil-fuel power plants in the rapidly growing arid regions of the nation.

Alan Steinman and Mark Luttenton of the Annis Water Resources Institute at Grand Valley State and Karl Havens of the South Florida Water Management District provide two case studies in sustainability from the states of Florida and Michigan. In each case, interactions between ground and surface water are key as is the effect of hydrological modifications on ecosystem services. The Florida case involves a water resources management technique that is rapidly increasing in application–aquifer storage and recovery (ASR)–which is found to have, not unsurprisingly, important effects on natural flow regimes that need to be managed for their effect on the Lake Okeechobee ecosystem. However, these effects are likely to be less damaging than the alternatives. In the Michigan case, demand for water withdrawals from the perceived-to-be abundant freshwater resources of the Great Lakes is being carefully evaluated for its potential effect on their topsy-turvy ecosystems. In attempting to practice water resources sustainability, both cases engaged both scientists and stakeholders in a messy political process, but decision-making was clearly improved by this broad engagement.

Daniel "Pete" Loucks, UCOWR's 2000 Warren Hall Medal winner from Cornell University, concludes the issue with a focus on "federal leadership in managing America's rivers." Loucks describes the fragmentation and lack of incentives for coordination of water resources decision-making in the United States. "Local decisions made today without consideration of how the entire system works can lead to tomorrow's problems." Substitute "local" with "narrow" or "single-purpose" and you have the other half of the equation. Loucks outlines a new federal river basin planning, granting, and coordinating agency that has the potential to start on the road from "management by lawsuits" to integrated, adaptive water resources management for sustainability.

Conclusion

Though this issue raises many questions it also provides some important answers. Water is capital that provides a flow of ecological as well as economic services, both of which are essential to human communities. Maintaining these services by maintaining the natural capital that produces them is the key to sustainability. Like the state of the nation's economy or ecosystems, sustainability can be measured albeit imperfectly. However, this measurement will require a continuing effort to reform the data gathering efforts of the nation to meet the needs of assessing our progress, or lack thereof. Implementing water resource sustainability is enormously difficult, and it will require legal, political, economic and institutional reforms for decades to come. In fact, given the inherent dynamism and ongoing evolution of complex,

feedback-rich systems, achieving sustainability is a never-ending task. However, implementing positive change has always been the challenge, and we all grow in the effort to meet it.