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A Six-Step Framework for Ecologically Sustainable Water Management

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Concern about the availability of freshwater for use by human populations has been increasing (Gleick 1998; Postel 1999; IUCN 2000; Postel 2000). Over the last 50 years, water development projects have proliferated in developed countries and are now rapidly growing in developing countries (WCD 2000). International debate has proffered sustainable water development—managing human uses of water such that enough water of sufficient quality is available for use by present and future generations—as a goal for human communities around the world (IUCN 2000). Unfortunately, this neglects the impacts water development projects have on other species. In the United States, freshwater species are the most imperiled and at risk for extinction (IUCN 2000; Pringle et al. 2000; Stein et al. 2000; Baron et al. 2002). To address the drastic consequences of unfettered human water use on freshwater ecosystems, concern for the species that depend upon freshwater to survive must be added to sustainable water management. The resulting *ecologically* sustainable water management retains the flows necessary to protect native species and sustain the full array of products and services provided by natural freshwater ecosystems while meeting inter-generational human needs for water (Richter et al. 2003).

The following six-step framework (Figure 1) is a guide for achieving ecologically sustainable water management (Richter et al. 2003). The fundamentals included in these steps have been developed and used by scientists, water managers, conservationists, and other professionals around the world. Packaging these together in a six-step framework creates a baseline of the critical elements required for meeting the goal of ecologically sustainable water management. The framework is a reference point that can be used to track progress toward ecologically sustainable water management. While these six steps are listed in a linear fashion and are numbered sequentially, it is for the purpose of simplifying their presentation. In many situations, these steps may occur in a different order or may be circled back to repeatedly.

The six step framework for ecologically sustainable water management is:

- Step 1: Estimate ecosystem flow requirements
- Step 2: Determine the influence of human activities on the flow regime
- Step 3: Identify incompatibilities between human and ecosystem needs
- Step 4: Foster collaborative dialogue to search for solutions
- Step 5: Conduct water management experiments to resolve uncertainties
- Step 6: Design and implement an adaptive management plan

Each of these steps will be described briefly and illustrated by a project with which The Nature Conservancy has been involved.

Step 1: Developing an Environmental Flow Recommendation

A river's flow regime varies in response to daily, seasonal, and annual climatic variability; species have evolved specific life history traits that utilize different aspects of the flow regime (Poff et al. 1997). Maintaining a river's natural flow variability is

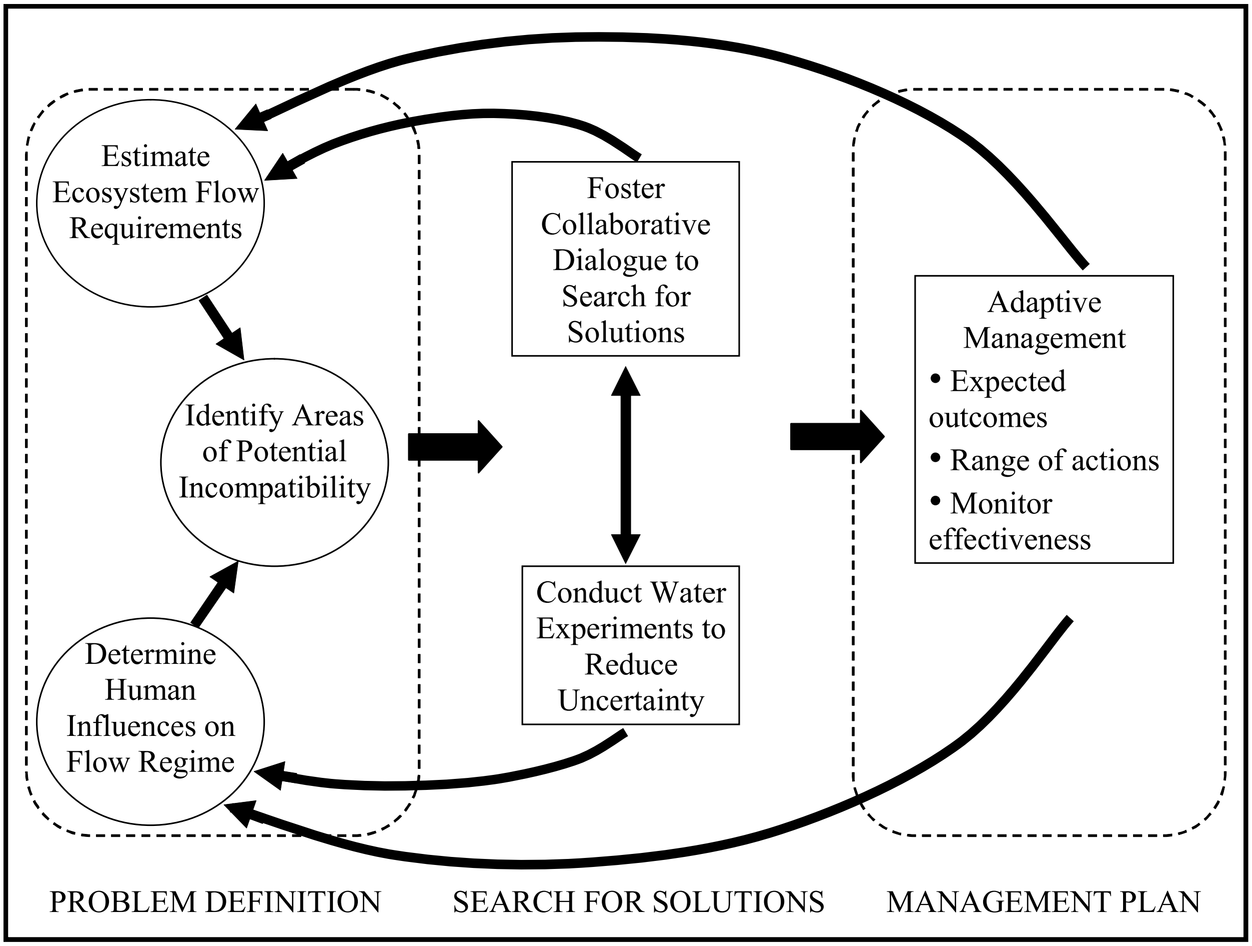

Figure 1. Six-step framework for ecologically sustainable water management.

essential for sustaining species diversity and the natural functions of ecosystems that provide goods and services valued by humans (Sparks 1995; Walker et al. 1995; Poff et al. 1997; Postel and Carpenter 1997; IUCN 2000). These flows are best described by the magnitude, timing, frequency, duration, and rate of change of specific flow components, including low flows, high flow pulses, and floods that will provide the conditions necessary to protect the full array of native species (Stanford et al. 1996; Poff et al. 1997; Richter et al. 1997).

In 2002-2003, The Nature Conservancy facilitated the development of environmental flow recommendations for use in the Army Corps of Engineers' new Comprehensive Plan for the Savannah River in Georgia and South Carolina. An interdisciplinary team of scientists and technical experts was convened and values were established for three components of the flow regime: low flows, high flow pulses, and flood events for dry, average, and wet years (see Richter et al. 2003b). These flow recommendations are expected to sustain or restore the ecosystems downstream of Thurmond Dam, defining the boundary within which water use and management would be ecologically sustainable. The recommended flows are initial estimates that will be tested and refined over time.

Step 2: Modeling Impacts of Human Uses on the Flow Regime

Humans use and manage water for a variety of purposes, including water supply, power generation, flood control, navigation, recreation, water quality, and irrigation. Each of these uses alters the flow regime in different, but characteristic, ways. A variety of tools, including hydrologic simulation models and the Indicators of Hydrologic Alteration (IHA) can be used to understand how a river's flow regime is being altered by existing or proposed future water use or management (Richter et al. 1996; Richter et al. 1997).

In 1997, the states of Alabama, Florida, and Georgia entered into an interstate compact to determine a water allocation formula for the Apalachicola-Chattahoochee-Flint River Basin (U.S. Congress 1997). The Apalachicola River and Bay at the mouth of this 20,000 square mile watershed is home to a diverse assemblage of fish and mussel species and sustains a nationally important commercial fishery (ANERR 1993; Hoehn 1998). The thriving metropolis of Atlanta and a large agricultural industry rely on the waters that would historically have flowed into the Apalachicola River and Bay. To demonstrate the compatibility of providing water for current and future human water uses and maintaining a natural flow regime in the Apalachicola River, The Nature Conservancy used a hydrologic simulation model developed by the three states to explore different levels of human demands and various reservoir operation scenarios. Impacts on the flow regime in the Apalachicola River were determined by evaluating output from this model using the IHA. An iterative process of modeling reservoir operations and human demands and subsequent IHA evaluation of resulting flows showed that a significant increase in human demands could be accommodated while maintaining the natural flow regime in the Apalachicola River (Richter et al. 2003).

Step 3: Changing Reservoir Operations for Ecosystem Benefit

Once the ecosystem flow requirements and human uses that influence the flow regime have been quantified, it is possible to identify where there are potential incompatibilities or conflicts between human uses of water and ecosystem flow needs. It is important to characterize these conflicts with as much specificity as possible to limit the extent of the conflict and bring focus to its possible resolution. In many cases, it is possible to adjust water use or management such that ecosystem flows are met while still providing water for humans.

The Green River Dam in Kentucky is operated by the Army Corps of Engineers to provide flood control in the winter and reservoir recreation in the summer. Downstream of the dam is one of the most diverse assemblages of fish and freshwater mussels in the United States, and the Mammoth Cave, home to a host of species that have adapted to the unique conditions in the cave. The transition from recreation lake levels to flood control storage levels has historically been accomplished by releasing a large volume of water during October. This resulted in dramatically elevated river flows during a time when flows naturally would have been very low. Scientists posited that these elevated flows could be harmful to fish spawning and mussel reproduction. Working with the district engineer, The Nature Conservancy and the Corps were able to design a new release pattern that would still meet the intended purposes of the Green River Dam but is expected to improve conditions for river species below the dam. To ensure these changes in reservoir operations do provide benefits to downriver species, a monitoring program was put in place (Postel and Richter 2003).

Step 4: Collaborative Process to Meet Diverse Interests

There are many processes in which the framework for ecologically sustainable water management can be applied, including: watershed planning, FERC relicensing, instream flow setting, interstate or transboundary water compacts, river basin commissions, species recovery planning, multi-party partnerships and dam re-operations. Whatever the setting, it is important for the parties to come together in an open collaborative process that enables stakeholders to articulate interests and clarify goals (Bingham 1986; Howitt 1992; Axelrod 1994). It will be necessary to examine where along the spectrum from a natural river to one that is highly managed for human uses a river, portion of a watershed, or watershed should be. Working together, the parties develop a shared vision for the river's future conditions that can be used in water management decisions, permitting, conservation, or restoration actions (Rogers and Bestier 1997). With the information gained through Steps 1, 2, and 3, the group can look for innovative solutions that will meet the intended goal. Having a common vision provides clear direction for managers interested in adaptively managing water resources.

The existing license for the Baker River Project in the Skagit River Basin in Washington expires in

2006. Relicensing proceedings have been in process for several years and include participation of Puget Sound Energy, federal and state agencies, tribes, local government, and non-governmental organizations.[1] The hoped for outcome of these negotiations is a license issued by FERC that will mitigate the impacts of the hydropower project on aquatic, terrestrial, recreation, and cultural resources within the Baker Basin and downstream of the project in the Skagit River. The project also provides flood control under the direction of the Army Corps of Engineers. Finding a solution that satisfies these diverse interests and is economically viable for the utility has required compromise and innovative solutions, including adaptive management.

Step 5: Building a Knowledge Base through Research and Monitoring

There is often insufficient information for determining ecosystem flows or the influences of water management and use on the natural flow regime with absolute certainty. This can create inertia in a collaborative process as uncertainty, inability to assign responsibility, and indecision reign. It is important to address areas of uncertainty and move forward out of this inertia. This can be done in a way that builds the information base for decision-making and frees energy to move forward where certainty does exist.

The San Pedro River is one of the last remaining free-flowing rivers in the American Southwest, and it is fed by the waters of an underground aquifer. Its cottonwood gallery forests, which provide critical habitat for migrating songbirds, depend upon aquifer levels shallow enough to be reached by their roots. Human population growth, irrigated agriculture, and a military base also rely on the groundwater. For a number of years, a single trend analysis of reduced baseflow in the river stymied possible solutions as each party placed responsibility for this declining trend on others. The Upper San Pedro Partnership composed of 20 agencies and organizations has been formed to break this deadlock (Upper San Pedro Partnership 1998). Investments in research and monitoring are being made to increase the understanding of the complex interrelationships between water use, the aquifer, and the ecosystem. While this work is in progress, the Partnership is moving forward with water conservation projects that will begin reversing the trend in groundwater depletion. As new information becomes available, the water resource conservation plan will be altered to better reflect current knowledge (Richter et al. 2003; Postel and Richter 2003).

Step 6: Stepwise Progression towards Ecological Sustainability

There will never be enough resources to resolve all of the uncertainties associated with setting ecosystem flows and managing water resources for human uses. To meet the goal of ecologically sustainable water management over the long-term, it is essential to have an institutional framework that incorporates new information as it becomes available. The goals articulated in Step 4 become the compass-point directing water resource managers (Rogers and Bestier 1997). A range of actions, or incremental actions, with expected outcomes from each action should be documented. As these actions are implemented, monitoring and evaluation will reflect whether the expected response has occurred (Walters and Holling 1990; Lee 1993). This allows for course corrections to meet the intended goals and provides new information that feeds back into Step 1 and Step 2.

In preparing the settlement agreement to be considered by the FERC in licensing the Roanoke Rapids Dam in North Carolina, The Nature Conservancy worked with the utility and other parties to incorporate the principles of adaptive management. Bottomland forests downstream of the dam were suffering from reduced recruitment rates, and it was hypothesized that increased flood frequency and duration during the growing season was the culprit. While not knowing exactly how much the utility needed to alter its operations to improve conditions for bottomland forest and other floral and faunal populations downstream of the dam, the Conservancy and others wanted to ensure that the new license protected or restored these species. To accomplish this, a goal for improving these populations was set, and a stepwise progression of operational changes was developed. To make this palatable to the utility and protect their interest in hydropower generation, a maximum amount of lost generation was agreed upon. Within that constraint, the utility would alter operations moderately, followed by a period of monitoring to establish whether the goals for species health were met. If they were, then the utility would not have to proceed with additional modifications. If they were not, the next increment of change in operations would be implemented and monitored. In this way, the utility would find the most efficient level of modification of operations that would meet the river restoration goals (Postel and Richter 2003).

Conclusion

These are just a few examples of an increasing number of efforts worldwide that bring the fundamentals of ecosystem science and adaptive management to water management and policy decisions. Society faces a growing body of evidence of the true costs of degraded freshwater ecosystems. Human social values are shifting in response. These changing values are reflected in legal and regulatory agreements requiring a more even balance between allocating water for economic and environmental uses. Scientists are making progress in understanding the dynamic environmental processes (e.g., flow regimes, sediment inputs, etc.) that are fundamental to a river's health and how these affect species survival and diversity. New tools are being developed to assist in this more holistic approach to water allocation. Adaptive management is being tested in both small and large river systems and is beginning to be accepted by both water managers and regulatory agencies as a way to provide certainty in an uncertain setting.

Non-governmental organizations (NGO), like The Nature Conservancy, have a valuable role to play in resolving water resource conflict and moving water management and use toward ecological sustainability. The parties involved in water resource decision making can often be split into two camps–those who regulate and those who litigate. The Nature Conservancy's commitment not to litigate, its lack of regulatory authority, and its willingness to work with all parties places it in a unique position. While carrying no stick at all, The Nature Conservancy and similar NGOs can promote innovative solutions that meet and mediate between diverse interests, thus providing options that agencies, tribes, utilities and others may not be able to advance but to which they can agree.

Ultimately, ecological sustainability is a choice that recognizes there is a limited supply of natural resources and that the health of human populations is inextricably linked to the health of natural ecosystems. Society has begun to move in this direction, and this framework is offered in support of this movement toward sustainability for all species.

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Ruth Mathews founded River Matters in 2004 to provide services that support ecologically sustainable water management (ESWM). Prior to that she worked for The Nature Conservancy where she led the application of ESWM in the Pacific Northwest by working collaboratively with water managers, scientists, water users, and other conservationists to protect and restore river flows in a variety of settings. Prior to living in the Northwest she represented The Nature Conservancy in water allocation formula negotiations for the Apalachicola-Chattahoochee-Flint River Basin. Ms. Mathews has a Master of Science in Water Resource Management and Planning from Colorado State University. She can be contacted at Ruth Mathews, 716 14th Street, Bellingham, WA 98225; riverspeaker@earthlink.net.

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Notes

1. Documents concerning the Banker River Project are online at http://www.pse.com/hydro/baker/index.html.