INCORPORATING ENVIRONMENTAL FLOWS INTO WATER MANAGEMENT

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The scientific community has made substantial advances during the past 10-20 years in understanding the relationship between patterns of river flow, and the health and ability of ecosystems to provide a range of goods and services valued by people. In general terms, this improved understanding recognizes that natural patterns of river flows – from seasonal low flows to periodic floods – are vital for maintaining the long-term health of our rivers and associated floodplains and estuaries. Unfortunately, these advances have not been integrated with or transformed water management practices during this same period. In fact, during the past half a century, societal demands for municipal water supplies, irrigation to support agriculture, industrial water use, flood control, hydropower generation and navigation have resulted in extensive modification of river flows. For example, 98 percent of the major rivers in the United States are regulated by dams. Moreover, these changes have impacted all components of river flows including ecologically important low flows, high flow pulses, and floods. Even when water management has considered environmental concerns, the focus has largely been limited to maintaining some level of "minimum instream flow." The significant improvements in the science of rivers of the past two decades currently influences actual management practices on only a very small percentage of the world's rivers.

Example River Flow Alteration Due to Dam Operations

- Decreased low flows due to agricultural or municipal water supply
- Elevated low flows to accommodate pollution discharges
- Loss of small floods (2-20 year events) for flood control, water supply, or hydropower
- Sustained high flows (near bankfull) for flood control
- Rapid and increased fluctuations in flow conditions for hydropower

Fortunately, an encouraging amount of work is going on globally to develop and implement innovative water policy and river-specific management practices that protect or restore ecosystem health while meeting human needs for water and energy. One process for defining and implementing river-specific environmental flows within an adaptive management context is outlined below, along with lessons learned from its application across the United States and – sparingly to date – in other countries. The focus here is on its application in helping to guide reservoir operations, although it is also applicable to other water management settings.

A process for defining and implementing environmental flows within an adaptive management context described by Richter *et al.* (2006) is being applied across the United States through a national collaboration between the U.S. Army Corps of Engineers (Corps) and The Nature Conservancy (Conservancy) under the Sustainable Rivers Project (SRP). While the SRP involves a range of efforts including formal personnel sharing, joint training, and joint software development (see the article by John Hickey in this issue), the cornerstone of the project is the work being advanced at demonstration sites across the country. There are currently nine river systems enrolled in the SRP involving 26 Corps dams (Figure 1), with additional dams and rivers under consideration. The goal of the project is to demonstrate ecologically sustainable water management so that it can be applied at the more than 630 dams operated by the Corps and by other water managers globally.

Environmental Flows

Flow of water in a river or lake that sustains healthy ecosystems and the goods and services that humans derive from them. Effective quantification of environmental flows includes the ecologically important range of flow magnitudes (low flows, high flow pulses, and floods), as well as the timing, duration, frequency, and rate of change of the flow conditions. Globally, "environment flows" is the most common term used, but "ecological flows" or the more dated "instream flows" are also used in some places to have the same intended meaning.

Environmental flows defined using the Savannah Process explicitly ignore all real or perceived constraints to their immediate implementation, including those that are physical, legal, social, political, or financial

Nicknamed the "Savannah Process" for the river where it was first applied, the process described in Richter *et al.* (2006) is designed to be science-based, deeply interdisciplinary, adaptive, and flexible enough to be customized based on available time and resources. The Savannah Process involves the following five basic steps (Figure 2):

1. *Orientation Meeting* – This is the kickoff of the Savannah Process, bringing together diverse scientists and representatives from all key agencies and organizations with water management interests in the basin. The remaining steps (Steps 2-5), expected timeline, products, costs, and roles and responsibilities are outlined and

Figure 1. Current Sustainable River Project Sites (May 2007).

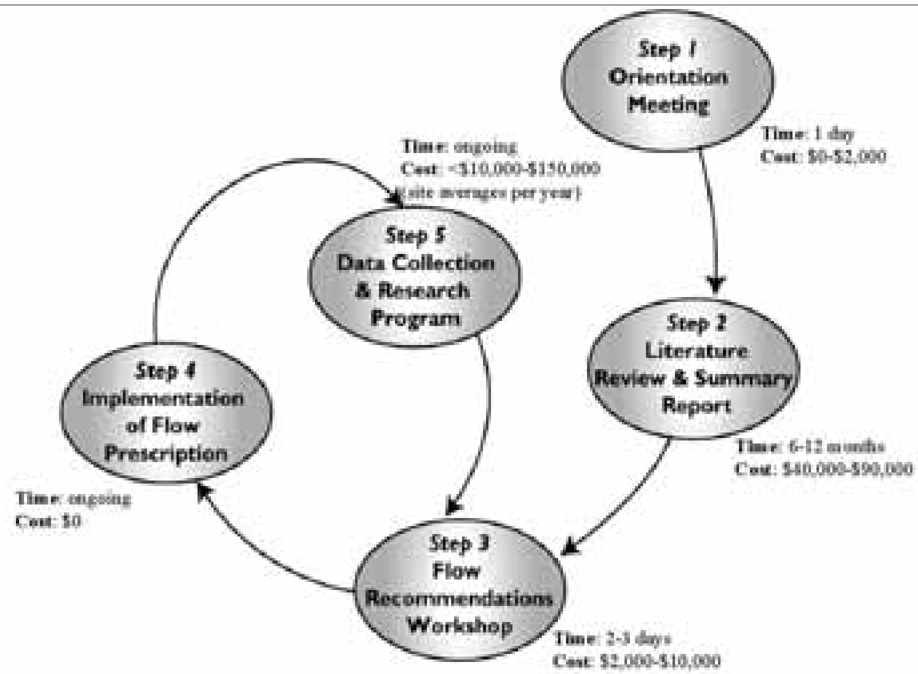

Figure 2. Process for Defining and Implementing Environmental Flows Within an Adaptive Management Context (the "Savannah Process") (modified from Richter *et al.*, 2006).

discussed. Orientation meetings have involved between 40 and 100 people.

2. *Literature Review and Summary Report* – A small team of scientists is tasked with: (a) conducting an extensive review of existing published research and gray literature related to flow-ecology relationships in the river and similar rivers in the region; and (b) synthesizing this information into a "summary report" designed to inform the environmental flow workshop (Step 3). This team has a designated lead, typically consists of 5-10 scientists, and needs to be diverse in its expertise. For example, a team might consist of a hydrologist or fluvial geomorphologist, fish and mussel experts, and riparian and estuarine ecologists. Drafts of both the literature review and summary report are distributed for comment to all who attended the orientation meeting, with comments addressed and the reports redistributed a month prior to the flow workshop.

3. *Environmental Flow Workshop* – This facilitated workshop, which is typically an intensive 2-3 day event, produces two very important products. The first is a unified set of environmental flow recommendations that give consideration to river, floodplain, and – where appropriate – estuarine systems, and encompass requirements for low flows, high flow pulses, and floods for different year types (e.g., climatically dry, average, and wet years). Each of the environmental flow components that make up the recommendations are quantified (flow magnitude, duration, timing, frequency, and rates of change) and explicitly stated in terms of the ecological processes that are hypothesized to support (Figure 3). The second product is a prioritized list of information gaps to help guide research and monitoring efforts. These flow workshops have involved between 35 and 90 people.

20,000-40,000 cfs; 2-3 days, 1/month (Jan-May)

- Provide predator-free habitat for birds
- Disperse tree seeds
- Transport fish larvae
- Flush woody debris from floodplain to channel
- Floodplain access for fish
- Fish passage past NSBLD

Figure 3. A Portion of the Environmental Flow Recommendation for the Savannah River. The magnitude, duration, and frequency of this controlled flood are quantified, as are the ecological processes that will be supported by the flow event.

4. *Environmental Flow Implementation* – This involves modifying reservoir operations or other water management practices to create river flows as called for in the workshop recommendations (Step 3). In terms of implementation, defined environmental flows tend to fall into one of three categories: (a) those that can be implemented immediately without significant conflict, (b) those that require study – typically involving computer modeling – to assess the implications of their implementation, and (c) those with significant social and/or economic implications that require long-term planning and likely substantial investment to implement.

5. *Monitoring and Research* – As noted above, a list of priorities for monitoring and research is one of the important products emerging from the flow workshop (Step 3). Each of the environmental flow components that comprise the recommendations is linked to specific ecological processes. They are, in effect, hypotheses that are tested through coordinated reservoir operations and monitoring. These hypotheses and the scientific knowledge gaps identified and ranked during the workshop provide a foundation for setting formal monitoring and research priorities.

The time and cost for this process varies. To date, environmental flows have been defined (Steps 1-3 completed) at six of the nine SRP sites, taking a total of six to 12 months and costing between $40,000 and $90,000. Environmental flows have been partially implemented (Step 4) at five of these sites, along with different degrees of associated monitoring and research (Step 5). Implementation involves planning, such as storing water earlier in the year, but it is also responsive to specific circumstances such as large rainfall events. Most of the engineer-scientist teams meet quarterly to discuss and coordinate reservoir releases and monitoring for the upcoming season. Estimated costs for monitoring and research at SRP sites range from a low of less than $10,000 to more than $150,000 per year. Sites at the higher end of this range are those where more intensive fieldwork was conducted to support computer model development.

Environmental flows defined using the Savannah Process explicitly ignore all real or perceived constraints to their immediate implementation, including those that are physical, legal, social, political, or financial. The purpose of the process is to define the river flows that are necessary to maintain long-term ecosystem health. Any necessary tradeoffs between this goal and other expectations for water management are made elsewhere. This approach to defining environmental flows has: (1) helped advance understanding of the ecosystem processes that will not be supported by different management options, and (2) highlighted opportunities to align ecosystem restoration or protection with other more traditional human demands for water such as improving flood control or hydropower generation.

In collaborating to move through the Savannah Process, water managers and scientists establish working relationships that are mutually beneficial. At each of the SRP sites where environmental flows have been defined and are being implemented, formal and informal conversations now occur between these groups on a quarterly, monthly, or even weekly basis. The engineers benefit from having real-time access to experts who can provide constructive guidance on how to meet multiple management objectives in the most ecologically beneficial (or at least benign) way. The scientists benefit by engaging the water managers – those who control river flows – as partners in research. As a collective, they are positioned to run experiments to determine how different flow conditions relate to ecosystem health and the goods and services humans derive from healthy ecosystems. This relationship is ongoing and allows for experimentation not only around a single event or for a single year, but for a long series of years. This directly supports adaptive management and serves to advance river science.

Finally, the Savannah Process has begun to see application beyond the SRP and the United States. The process is currently being used to define environmental flows for municipal water supplies involving dams and ground water extraction in places such as the Rivanna River in Virginia and the Verde River in Arizona. The process is also being applied in China and Honduras, the latter of which is faced with a dearth of scientific information and is relying heavily on indigenous knowledge. It is in part this flexibility that has gained the process a growing acceptance. Moreover, it is the pairing of engineers and scientists through the process that will lead to improved management, advances in science, and better protection and restoration of rivers globally.

REFERENCE

Richter, B.D., A.T. Warner, J.L. Meyer, and K. Lutz. 2006. A Collaborative and Adaptive Process for Developing Environmental Flow Recommendations. River Research and Applications 22:297-318.

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