RESTORING ENVIRONMENTAL FLOWS THROUGH ADAPTIVE RESERVOIR MANAGEMENT: PLANNING, SCIENCE, AND IMPLEMENTATION THROUGH THE SUSTAINABLE RIVERS PROJECT

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River managers worldwide are increasingly addressing flow needs for ecosystem processes and services in their management plans for dams and reservoirs. However, while planning and scientific assessments have advanced substantially, successful re-operation of infrastructure to achieve environmental benefits has been more limited. The Sustainable Rivers Project (SRP) was formalized in 2002, as a national partnership between the United States Army Corps of Engineers and The Nature Conservancy to define and implement environmental flows through adaptive reservoir management. The Project has focused on eight demonstration basins containing 36 Corps dams, but is designed to direct the collective experience from these sites to help guide agency-wide operational changes for as many as 600 dams to benefit up to 80,000 river kilometres and tens of thousands of hectares of related floodplain and estuarine habitat. This paper summarizes the progress to date on defining and implementing environmental flows through the SRP, and evaluates the technical, social, legal, and institutional factors that act as dominant enabling conditions and constraints to implementation.

1 INTRODUCTION

Natural hydrologic patterns in river systems are widely recognized as critical for maintaining the integrity of ecosystems and a diversity of services they provide for people [1-5]. The construction and operation of dams is a leading cause globally of hydrologic change and the associated disruption of freshwater ecosystems [6-8]. While dams have a range of impacts on river systems, not all of which can be mitigated [8], changing dam operations to incorporate environmental flows provides a particularly compelling strategy to achieve environmental benefits due to the specific and discrete management actions involved. For similar reasons, reservoirs lend themselves to adaptive management where adequate operational flexibility exists or can be expanded and where appropriate institutional mechanisms exist or can be created.

While there is a large number of sites where environmental flows have been defined to guide adaptive reservoir management, there is a relative dearth of examples of environmental flow implementation [9, 10]. Consequently, many unanswered questions remain about the necessary circumstances for accomplishing environmental flow implementation. One set of "proof-of-concept" sites exists in the Sustainable Rivers Project (SRP) launched in 2002. Here we discuss the types and degrees of environmental flow implementation and related adaptive reservoir management efforts at SRP sites, along with the obstacles and enabling conditions – including scientific/technical, socio-economic, legal, and institutional issues – that have been most influential to implementation.

2 SUSTAINABLE RIVERS PROJECT OVERVIEW AND STATUS

The SRP consists of eight initial demonstration sites located across the continental United States, including the Connecticut River, Roanoke River, Savannah River, Green River, White River, Big Cypress Bayou, Bill Williams River, and Willamette River (Figure 1), which contain a total of 36 United States Army Corps of Engineers (USACE) dams. The underlying basis of the SRP is the use of a collaborative, science-based process for defining, implementing and evaluating environmental flow prescriptions on either a river-specific [11] or regional [12] basis, either of which can be summarized into the four general phases of work shown in Table 1.

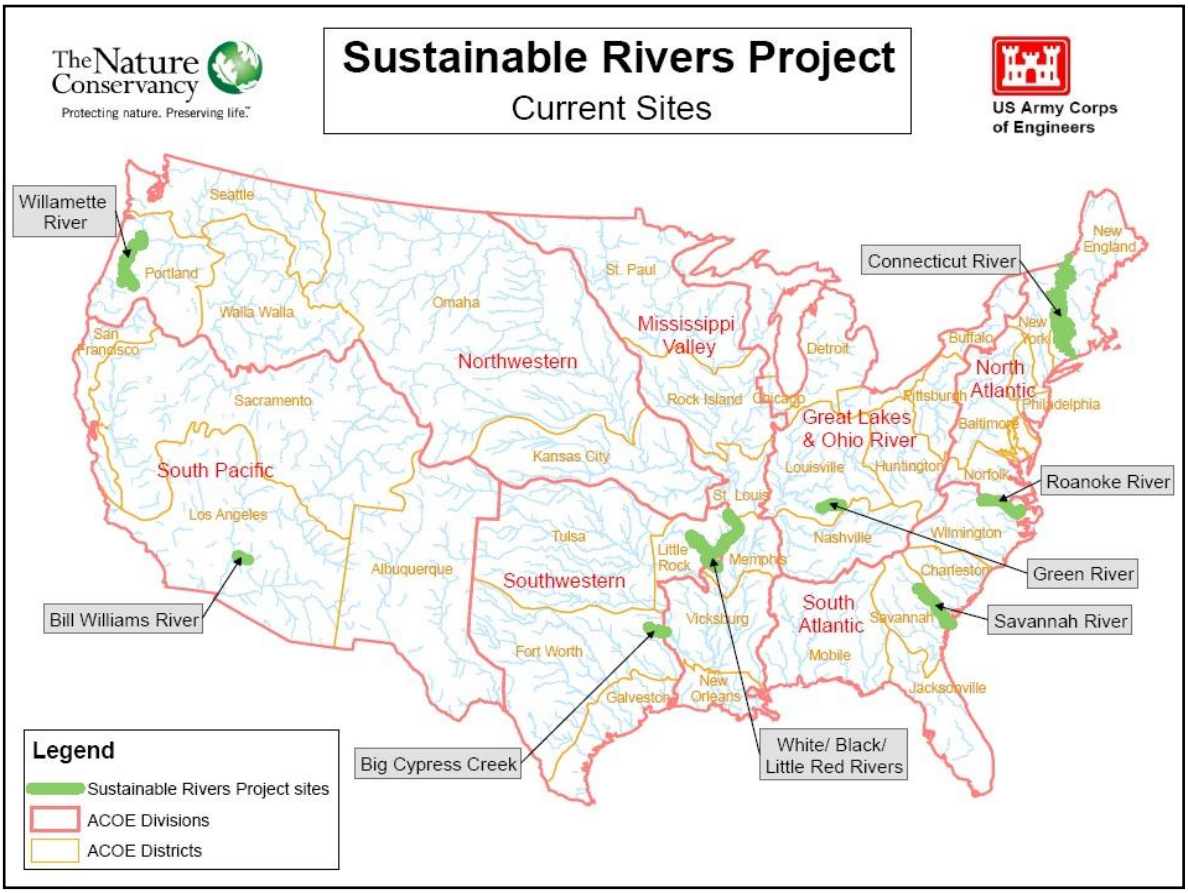

Figure 1: Initial eight demonstration sites in t he Sustainable Rivers Project (SRP).

For the eight initial demonstration sites, a total of 36 dams are engaged in the process, affecting 2,968 river kilometres and tens of thousands of hectares of associated floodplain and estuary habitat.

Viewed collectively, progress made through the SRP has been successful across all the primary phases of work. SRP sites have engaged a wide diversity of stakeholders in a process of identifying and synthesizing hydro-ecological relationships and using that information to define holistic environmental flows. Environmental flows have been implemented at six sites involving 11 dams, with water managers and scientists constructively collaborating on both real-time and longer term reservoir operations, and associated monitoring and documentation of ecological responses and impacts on other project purposes. Environmental flow prescriptions are being incorporated into on-going modelling and management of reservoir operations and, in the case of the Green River, the reservoir water control plan was revised to incorporate environmental flows. In order to facilitate further advances at individual sites and enhance the effectiveness of the overall project for helping to catalyse broader environmental flow implementation, common obstacles and enabling conditions are summarized below.

3 RESULTS AND CONCLUSIONS

The Sustainable Rivers Project has demonstrated that a voluntary and collaborative approach can be successful for defining and implementing environmental flows through changes in reservoir operations under a range of ecological and social/institutional circumstances. To date, some degree of environmental flow implementation has been carried out at six of the SRP sites, involving a total of 11 dams affecting approximately 1,000 kilometres of river. This success has relied on an open process and use of the best available knowledge. Knowledge gaps and uncertainty – too often sources of conflict and stagnation – are instead translated into drivers for action in the form of experimental flow releases and monitoring that are coordinated between reservoir operators and scientists. This strengthened collaboration between reservoir operators and scientists has been one of the more valuable aspects of the voluntary approach, providing a foundation for both site-based

advances and contributions to the broader knowledge of hydro-ecological relationships and supporting models and decision support tools.

While conflicts between environmental flows and other social objectives exist at SRP sites, the common assumption of certain conflict is categorically false. In fact, as demonstrated, opportunities exist to modify operations to both restore environmental conditions and enhance traditional reservoir purposes such as water supply, hydropower generation, and recreation, especially at older reservoirs that have not undergone recent operational review. Flood risk management goals also can be enhanced through efforts to define and implement environmental flows, especially when reservoir re-operations are explored more explicitly in tandem with downstream floodplain mitigation and restoration opportunities. Both aging water infrastructure and encroaching development in floodplains below dams have been recognized as real constraints to environmental flow implementation, and can similarly constrain other reservoir purposes. Addressing these constraints will require investments that – while uncertain in the current economic and political climate – hold substantial potential to modernize the country's water infrastructure and its management, thereby delivering more benefits and enhancing social and ecological resilience to future conditions.

While not dismissive of legal requirements and regulations, voluntary governance mechanisms have been shown to be very effective throughout the process to define and implement environmental flows through adaptive reservoir management, including supporting coordination of releases, monitoring, and allocation of limited resources. However, in the absence of a single authority or program to drive progress, developing a clear implementation plan has become recognized as important to a site's transition from simply having environmental flows to formally incorporating them into revised operations. More rapid progress through implementation at individual SRP sites could also help to further catalyse environmental flow work by the USACE and its partners beyond the largely "organic" expansion of the SRP to date. A more systematic expansion is being anticipated, to include work that will support prioritizing sites and resource allocation so the greatest benefits can be realized, while maintaining the long-term goal of helping to guide operational changes for as many as 600 dams that to benefit up to 80,000 river kilometres and tens of thousands of hectares of related floodplain and estuarine habitat.

Table 1. Summary of progress to date on implementing environmental flows through adaptive management of the 36 U.S. Army Corps of Engineers' dams in the eight initial *Sustainable Rivers Project* demonstration sites, along with the estimated affected river kilometres.

Phase of the Process	Number of Dams	Estimated Affected River Kilometres
1. Initiating the Process	5	703
2. Defining Environmental Flows	20	1,271
3. Implementing Environmental Flows	10	805
4. Adaptively Managing Dams	1	189
Totals:	**36**	**2,968**

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