Credit: Evan Lowenstein

Sustainable Rivers Program Cost–Benefit Analysis

Final Report

Prepared for

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Contents

Figures

Tables

Executive Summary

The Nature Conservancy (TNC) engaged RTI International to evaluate the economic and ecological impacts of the Sustainable Rivers Program (SRP). This assessment estimates the monetary value of ecosystem services generated through SRP, which modernizes dam operations to improve river health while maintaining authorized uses such as navigation, hydropower, and flood risk reduction. The study focuses on four case study sites—Melvin Price Locks and Dam (Illinois–Missouri), Des Moines River (Iowa), Caddo Lake/Big Cypress Bayou (Texas-Louisiana), and Green River (Kentucky)—and extends results to provide an order-of-magnitude estimate for the broader SRP portfolio.

Since the 1930s, the U.S. Army Corps of Engineers (USACE) has constructed and managed large dams to meet national needs. USACE is in the process of updating many of its infrastructure management plans to better reflect new engineering technologies, changing stakeholder needs, and increased understanding of ecological impacts and opportunities. SRP, launched in 2002, is a partnership between USACE, TNC, and diverse stakeholders such as the U.S. Fish and Wildlife Service, state natural resource departments, local water utilities, and academic institutions. Its mission is to integrate environmental strategies such as environmental flows (e-flows) and environmental pool (e-pools) management into dam operations, thereby enhancing ecosystem function and community resilience.

This study used a mixed-methods approach, combining literature review, expert interviews, and quantitative cost–benefit analysis (CBA). Benefits were estimated using a transfer regression framework applied to 55 valuation studies covering ecosystem services such as maintenance of life cycles, soil fertility, water purification and waste treatment, regulation of water and sediment flows, erosion prevention, and recreation and tourism opportunities. Cost data were provided by USACE for 2010–2024. The analysis compared baseline (no-action) and SRP implementation scenarios, with results projected and values quantified through 2040.

> *“These results indicate that SRP investments consistently generate substantial economic returns, with benefits exceeding costs within a few years at most sites.”*

Key Findings

- Melvin Price Locks and Dam: Net Present Value (NPV) of $2.70 million and benefit–cost ratio (BCR) of 12.43 by 2040; benefits exceed costs within three years, based on cumulative benefits and costs evaluated from 2021 through 2040.
- Des Moines River: NPV of $17.70 million and BCR of 8.98; benefits exceed costs by 2028, based on analysis of cumulative benefits and costs from 2015 through 2040.
- Caddo Lake/Big Cypress Bayou: NPV of $2.86 million and BCR of 7.89; benefits exceed costs within five years, generating positive returns from 2015 onward, with evaluation covering the period from 2012 through 2040.

- Green River: Roughly $20 million in realized benefits since 2010, projected to exceed $37 million by 2040, with cumulative benefits assessed over the 2010–2040 period. Since complete cost data were unavailable, results are expressed as cumulative discounted benefits rather than BCR or NPV.
- Portfolio-level: Including the four case study sites and additional program sites, the program yields an estimated NPV of approximately $265 million and a BCR of 13.69 under Scenario 1, representing an optimistic ecosystem recovery condition, and an estimated NPV of approximately $243 million with a BCR of 12.63 under Scenario 2, representing a more conservative recovery scenario.

These results indicate that SRP investments consistently generate substantial economic returns, with benefits exceeding costs within a few years at most sites. The SRP demonstrates that modernizing dam operations can deliver high-value ecosystem services while supporting multiple authorized uses of federal water infrastructure. Despite uncertainties inherent in benefit transfer methods, the results are robust in both direction and magnitude. SRP is cost-effective both in the short term and over the full evaluation horizon, underscoring its value as the largest and most comprehensive program of its kind in the United States. Continued investment will ensure that ecological and economic benefits persist and expand across diverse river systems.

“SRP is cost-effective both in the short term and over the full evaluation horizon, underscoring its value as the largest and most comprehensive program of its kind in the United States.”

1. Introduction

TNC engaged RTI International, an independent scientific research institute, to evaluate the impacts of SRP. This report presents the results of our study, which monetizes the benefits provided by improved ecosystem services following SRP investments. These benefits are associated with implementing environmental actions that improve river health and ecosystem function while modernizing dam operations and maintaining or enhancing authorized uses such as navigation, hydropower, and flood risk reduction. We focus on case studies of benefits at specific sites and also use the collected information to estimate the benefits across the broader SRP portfolio.

This report evaluates the economic and ecological impacts of SRP to more fully describe SRP's impacts to decision-makers and stakeholders, including USACE leadership, policymakers, funders, local partners, and the public. It estimates the economic value of ecosystem services[1] enhanced by SRP at four sites—Melvin Price Locks and Dam (Illinois–Missouri; hereafter referred to as Mel Price), Des Moines River (Iowa), Caddo Lake/Big Cypress Bayou (Texas-Louisiana; hereafter referred to as Caddo Lake), and Green River (Kentucky)—and provides a rough estimate of benefits across a portfolio of 16 SRP projects. To accomplish this, we employed a mixed-methods approach that combines literature review, expert interviews, and quantitative analysis. Our qualitative assessment documents expected benefits from environmental actions implemented through SRP. Our quantitative analysis uses CBA to estimate the economic value of ecosystem services enhanced by SRP projects, starting from the year the project transitions from the start-up phase through 2040.

The remainder of this report is organized as follows. Section 2 provides additional background on SRP, including its history, goals, and implementation framework. Section 3 describes the data sources and methodological approach used to estimate the benefits of SRP projects. Section 4 presents the results of the CBA for the four case study sites, including key economic metrics such as net present benefits, net present costs, NPV, and BCR. Section 5 extends this analysis to estimate the overall benefits of the SRP portfolio. Finally, Section 6 concludes with a summary of findings and limitations.

[1] Ecosystem services are the benefits that humans derive from ecosystems and classified into four categories: provisioning, regulating, cultural, and supporting services.

2. SRP Background

Beginning in the 1930s, USACE built hundreds of large dams to meet the nation's growing needs for navigation, flood risk reduction, and hydropower. USACE is in the process of updating many of its infrastructure management plans to better reflect new engineering technologies, changing stakeholder needs, and increased understanding of ecological impacts and opportunities. SRP works with water managers, reservoir operators, scientists, and other stakeholders to help modernize dam operations to enhance community, economic and environmental benefits provided by existing infrastructure.

Initiated in 1998 as a pilot on the Green River in Kentucky and formally launched in 2002, SRP is a partnership between USACE, TNC, and state, federal, academic and other nonprofit partners. Its mission is to enhance the ecological performance of existing water infrastructure by integrating environmental strategies into dam operations without compromising authorized purposes. SRP operates through a structured process under which each participating site progresses through a framework of Advance, Implement, and Incorporate phases[2] (USACE & TNC, 2025). As of 2024, SRP has engaged more than 50 teams across 27 USACE districts. It is the largest and most comprehensive program for implementing environmental strategies such as e-flows, e-pools, and conservation locking at federal reservoirs.

E-flows, a strategy to manage the quantity, timing, and quality of water flows required to sustain ecosystems, are at the core of SRP's approach. When paired with complementary actions such as e-pools at reservoirs, e-flows support ecological functions critical to river health. By restoring flow regimes and associated habitat conditions, SRP projects have improved fish migration and life cycle support, enhanced water quality and sediment transport, reconnected floodplains and revitalized wetlands, increased opportunities for recreation, tourism and wildlife viewing, and boosted fish populations in reservoirs, among other benefits.

In each river system, SRP collaborates with local stakeholders to design and implement flow prescriptions and reservoir operations that achieve measurable ecological outcomes. These outcomes, documented through SRP's Metrics Framework, include improvements in river miles and habitat acres affected, species supported, and ecosystem services delivered (Sustainable Rivers Program, 2025). Ultimately, SRP's documented results show how modernizing dam operations can unlock the full environmental potential of existing infrastructure, delivering substantial ecosystem service benefits while supporting resilient communities and sustainable economies.

[2] **Advance** involves engaging stakeholders in a science-based process to define the flow needs of riverine ecosystems. **Implement** focuses on testing the effectiveness and feasibility of the defined flows. **Incorporate** entails embedding e-flow management actions into reservoir operations policies, such as water control manuals.

3. Data and Methods

3.1 Data Sources

To estimate the benefits of implementing SRP at each of the four sites, we used a combination of primary and secondary data sources. Primary data were collected through interviews and surveys with TNC and USACE staff at each project site. Secondary data included internal SRP documents, project reports, and GIS data describing site-level ecological characteristics. Below, we describe each data source in detail.

3.1.1 Expert Interviews

At each project site, we conducted two rounds of interviews and a structured survey with key project personnel. The first interview aimed to understand the local context, including the historical, cultural, social, economic, and ecological significance of the site. Specific goals were first to identify environmental actions introduced under SRP. The second goal was to document the intended benefits of each environmental action. We considered a wide range of benefits including improvements in wetland and floodplain function, enhancement of aquatic habitat, and support for wildlife and fisheries, among others.

Following this initial interview, we synthesized the information and created a site-specific inventory of environmental action interventions and their intended benefits. Each benefit was then mapped to relevant ecosystem services using The Economics of Ecosystems and Biodiversity (TEEB) classification system (de Groot et al., 2021). TEEB was selected because it offers a comprehensive and internationally recognized framework for identifying and categorizing ecosystem services, ensuring comparability with other studies and consistency in terminology. Appendix Table A-1 lists all ecosystem services included in the TEEB classification.

During the second interview, we reviewed this inventory with site representatives to validate the identified interventions and intended benefits and confirm or correct associated ecosystem service choices. Following the second interview we provided site representatives with a survey to collect additional information regarding the conditions of each ecosystem attribute affected by the environmental action, the temporal scale over which benefits were expected to accrue, and the geographic scale at which benefits are observed or anticipated to occur. These inputs, along with secondary data, informed key site-level characteristics used in the benefit estimation framework described below.

3.1.2 Secondary Data Collection

TNC and USACE staff provided budgetary and financial data on program implementation costs at the project-site level. We reviewed SRP administrative documents, internal reports, and published research to supplement and cross-validate information on intended benefits. These sources also provided spatial data, such as the number of acres or river miles affected by each environmental action (Sustainable Rivers Program, 2025). Finally, we used GIS to generate total hectares of relevant ecosystems per site.[3]

3.2 Methods

3.2.1 Costs

We used actual site-level annual costs for environmental action implementation, as reported by TNC and USACE staff managing SRP activities, covering the period from initial Advance phase through 2024. Cost components across all four sites included a wide range of activities necessary to support projects, such as planning and preparatory analyses (modeling, mapping, and baseline data collection), as well as monitoring and evaluation efforts (vegetation, soil, hydrologic, and fish and wildlife studies). Additional components involved coordination, reporting, and the integration of findings into management frameworks.

Mel Price entered the Advance phase in 2021, with total reported SRP expenditures of $218,000 from 2022 to 2024. The Des Moines site entered the Advance phase in 2015, with total reported expenditures of $2,040,155 through 2024, and cost data beginning that same year.[4] Caddo Lake reported $320,000 in total expenditures from 2010 through 2020, although the site entered the Advance phase in 2004. Finally, the Green River project recorded $205,000 in total expenditures from 2010 to 2024; although the site entered the Advance phase in 2002, cost data prior to 2010 were unavailable. For consistency, all cost data through 2024 were adjusted for inflation, and costs projected beyond 2024 were discounted.[5] Since our cost information only covers 2010–2024, the analysis does not account for expenditures prior to 2010, particularly for Caddo Lake and Green River.

SRP's role concludes at the prescription and planning stage, after which site staff continue implementation without SRP-funded operations or maintenance. Historical cost patterns reflect this approach, with many out-years showing zero expenditures and only occasional monitoring costs at a limited number of sites. Because the analysis values benefit relative to SRP's incremental investment, and the costs of implementing SRP-recommended changes to operations are folded into the duties of USACE officials who already manage operations at these facilities, our analysis assumes that post-2024 costs are zero. However, recognizing that this assumption may underestimate potential ongoing costs, we conducted a sensitivity analysis

[3] The number of hectares per site was estimated using a combination of information from the SRP metrics framework and geographic descriptions provided by site representatives in the survey.
[4] According to TNC staff, estimated costs at Des Moines are much higher than at other sites due to extensive research and monitoring efforts conducted in collaboration with universities and the State of Iowa, including studies on shorebird health, fisheries, and wetlands.
[5] The cost data we collected are not evenly distributed across the years from when projects entered the Advance phase through 2024. In some cases, costs were zero for most years. For example, data from TNC and USACE show annual expenditures for the Green River project in 2016, 2023, and 2024, even though it officially entered the Advance phase in 2002. This pattern reflects how SRP provides targeted support during specific phases—primarily the Advance and Implement stages. Once planning and management prescriptions are completed, SRP's direct funding ends, and site partners (such as USACE or state agencies) continue implementation and monitoring using their own budgets. Consequently, years without new SRP-funded activities or monitoring appear as "zero-cost" years.

in which future costs were assumed to equal 50% of total costs to date, distributed evenly over the remaining analysis period.

3.2.2 Benefits Estimates

To estimate the benefits of each SRP project, we first applied a benefit transfer approach[6] using a meta-analysis value transfer function. Specifically, we estimated a meta-regression model that predicts ecosystem service values (in 2025 USD per hectare per year) as a function of site and study characteristics. Following Brander et al. (2012) and Amatucci et al. (2024), we used the Ecosystem Services Valuation Database (ESVD)[7] to estimate the following meta-analysis regression:

$$ES_i = \beta_0 + \beta_1 X_{i,1} + \beta_2 X_{i,2} + \beta_3 X_{i,3} + B_4 X_{i,4} + \epsilon_i, \quad (1)$$

where, ES_i denotes the ecosystem service value of study i, expressed in 2025 U.S. dollars per hectare per year. The subscript i refers to a study from the ESVD database. β_0 is the constant term; $X_{i,1}$ denotes the vector of study characteristics (e.g., valuation method); $X_{i,2}$ includes site characteristic (e.g., ecosystem condition, area), $X_{i,3}$ indicates dummy variables for biome (e.g., rivers and lakes, temperate forest and woodland); and $X_{i,4}$ represents dummy variables for ecosystem services (e.g., moderation of extreme events, regulation of water flows)[8]. Finally, ϵ_i denotes the error term.

The regression model specified in Equation (1) was estimated once using a log-linear specification, where the dependent variable represents the natural logarithm of ecosystem service value (2025 USD per hectare per year). Table A-2 in the Appendix provides summary statistics for all variables included in the meta-analysis, and Table A-3 reports the estimated coefficients obtained from Equation (1). The estimation was based on a dataset of 55 valuation studies drawn from the ESVD database. Our estimates are consistent in both significance and direction with those of Amatucci et al. (2024) and Branders et al. (2012). However, our analysis is based on a subset of ESVD studies focusing exclusively on four biomes (intensive land use, rangelands and natural grasslands, rivers and lakes, and temperate forest and woodland) whereas Branders et al. rely on all available studies and Amatucci et al. uses a different subset of studies.[9]

The estimated coefficients ($\hat{\beta}'s$) from Equation (1) were then applied to predict the monetary value of each ecosystem service m present at each site s. Site-specific predictor variables were

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[6] Benefit transfer is an economic valuation method that applies results from existing primary studies to estimate the value of ecosystem services or policy impacts at sites where original valuation data are unavailable. While primary research is ideal, benefit transfer is often the most practical approach for informing policy decisions when time or resource constraints prevent new data collection (Johnston and Rosenberger, 2010).

[7] https://www.esvd.net/. Table A-1 lists all the ecosystem services available in the ESVD dataset.

[8] Each ecosystem service dummy variable takes the value of 1 if the corresponding ecosystem service is present and assessed in the study site, and 0 otherwise.

[9] The analysis focuses on four biomes because they are the most closely associated with river and freshwater ecosystems represented in SRP project sites. Studies focused on other biomes (e.g., marine, coastal, tropical and subtropical forests, deserts, and semi-deserts) were excluded, as they are not relevant to the hydrological and ecological contexts of SRP.

populated using information from expert interviews and GIS-derived datasets, including indicators of ecosystem condition, area, land cover, and biome classification.

For each SRP site, the relevant dummy variables were assigned based on the site's ecological and service characteristics. For example, when estimating the value of the ecosystem service maintenance of life cycles for a site located within the rivers and lakes biome, the corresponding dummy variables for that ecosystem service and biome were set to one, while other dummies were set to zero. For all estimated ecosystem service values, the market price dummy variable was set to one, as this valuation methods tend to provide more conservative estimates compared to other available valuation approaches.

The total annual ecosystem service benefit for site s, denoted EB_s, was calculated as:

$$EB_s = \sum_{m \in ES_M} ES_m = \sum_{m \in ES_M} \left(\widehat{\beta_0} + \widehat{\beta_1} X_{s,1} + \widehat{\beta_2} X_{s,2} + \widehat{\beta_3} X_{s,3} + \widehat{\beta_4} X_{s,4} \right), \quad (2)$$

where ES_m represents the estimated value of ecosystem service m predicted from the meta-regression, and ES_M denotes the set of all ecosystem services considered at site s. Table 3-1 lists the site-specific variables used in these estimations, derived from expert input and spatial data on mean species abundance and dominant land cover.

3.2.3 Net Benefits Estimates

We used Equation (2) to estimate the total annual ecosystem service values for each intended benefit at each site under two scenarios. The first was the no-action baseline scenario, in which the ecosystem condition—categorized as degraded (severely impaired and potentially collapsing), intermediate (moderately modified but still functioning), or good (ecologically healthy and resilient)—reflected the state prior to SRP implementation, as reported by site experts in their survey responses. The second was the post-implementation scenario, representing the current and maximum ecosystem conditions after SRP.

This change in ecosystem condition was incorporated directly into the meta-analysis estimated with Equation (2) through adjustments to the corresponding explanatory variable. Table 3-1 reports the condition transitions from prior to SRP (baseline) to after implementation (current and maximum) for each expected benefit–ecosystem pair. The net expected benefit of SRP at each site is defined as the difference in total annual ecosystem service value between the implementation and baseline scenarios.

Table 3-1 Environmental Actions, Intended Benefits, and Site Condition Across SRP Projects (Based on Expert Survey Responses)

Site	Start Year	Env. Action	Intended Benefit	Area (ha)	Relevant Site Conditions			Years (from current = 2024) until Maximized Benefits Are Realized
					Baseline	Current	Maximum	
Mel Price	2021	EF	Lake Sturgeon/ Fisheries	24	Degraded	Intermediate	Good	6 to 10
		EP	Waterfowl	451	Degraded	Good	Good	6 to 10
			Shorebirds	451	Degraded	Intermediate	Good	11 to 20
			Fisheries	451	Degraded	Intermediate	Good	11 to 20
			Wetland Vegetation	451	Degraded	Intermediate	Good	6 to 10
			Water Quality	NA	Degraded	Degraded	Degraded	NA
Des Moines	2015	EF	Mussels	695	Degraded	Degraded	Intermediate	6 to 10
			Fisheries/ Sturgeon	695	Degraded	Degraded	Good	6 to 10
		EP	Herptiles	6,281	Degraded	Degraded	Intermediate	6 to 10
			Shorebirds	1,214	Degraded	Degraded	Good	6 to 10
			Water Quality	1,298	Degraded	Degraded	Intermediate	6 to 10
			Wetland Vegetation	NA	Intermediate	Intermediate	Intermediate	NA
Caddo Lake	2010	EF	Fisheries	809	Intermediate	Good	Good	6 to 10
			Floodplain Connectivity	809	Degraded	Degraded	Intermediate	More than 20
		EP	Water Quality	809	Intermediate	Good	Good	6 to 10
			Flood Protection	809	Degraded	Degraded	Intermediate	More than 20
Green River	2002	EF	Mussels	4,989	Degraded	Intermediate	Good	11 to 20
			Fisheries	4,989	Degraded	Intermediate	Good	6 to 10
		EP	Recreation	1,331	Intermediate	Good	Good	3 to 5
			Habitat Enhancement	1,331	Degraded	Intermediate	Good	11 to 20

Notes: EF = E-flows; EP = E-pools

Ecosystem conditions:

a. *Degraded:* Ecosystems are severely impaired and potentially collapsing

b. *Intermediate:* Ecosystems are moderately modified but still functioning

c. *Good:* Ecosystems are ecologically healthy and resilient

Ecosystem conditions vary across three temporal scales. Baseline, the ecosystem's condition before SRP implementation, used as the reference point for comparison; current, the current ecosystem condition as of 2024; maximum, the potential best-case ecosystem condition achievable with full SRP success.

Although interventions at the Des Moines site have been in place for approximately 10 years, survey responses indicate that ecosystem conditions for the intended benefits have not changed from the baseline to the current. Therefore, we assume that maximum benefits will begin to accrue after the ten-year mark.

3.2.4 Cost–Benefit Analysis (CBA)

To evaluate the overall economic performance of SRP actions at each site, we conducted a CBA comparing annual program costs to projected annual ecosystem service benefits. For each site, the analysis period begins when SRP transitions from the Advance to the Implement or Incorporate phase and extends to 2040. This duration was determined based on expert input to ensure that all major expected benefits are realized.

We applied a real discount rate of 7% to compute the present value of both costs and benefits and conducted a sensitivity analysis using alternative rates of 3.25% and 10%, with the 3.25% rate reflecting the official federal interest rate for USACE projects related to economic evaluation for water and related land resources. Discounted values were then used to calculate the present value of benefits and the present value of costs. Additionally, we conducted an additional sensitivity analysis in which future costs were assumed to increase from zero to 50% of total costs to date, distributed evenly over the remaining analysis period. The resulting CBA metrics include NPV, defined as the difference between the present value of benefits and the present value of costs, and the BCR, defined as the present value of benefits divided by the present value of costs.

4. Measures of Economic Benefit

4.1 Case Study 1: Mel Price Lock and Dam

Credit: Missouri Department of Conservation

Benefit–Cost Highlights for Mel Price SRP

- $2.94 million in total discounted benefits versus $0.24 million in costs through 2040; NPV of $2.70 million.
- BCR: 12.43 by 2024; every dollar invested yields over twelve dollars in returns.
- Benefits exceed costs within three years, demonstrating early positive returns.
- Annual current benefits range from $12,000 for lake sturgeon and fisheries to $231,000 for waterfowl, shorebirds, and fisheries, with total potential annual benefits of $270,000.
- Sensitivity tests confirm BCR remains above 10 under all discount rate scenarios (10.41 at 10%, 15.92 at 3.25%).

Mel Price is located at river mile 200.78 on the Upper Mississippi River, approximately 17 miles north of St. Louis, Missouri. Operated by the USACE St. Louis District, the structure maintains a 9-foot navigation channel critical to commercial transport on the river. The facility includes a public museum and educational center, offers regular public tours, and attracts visitors year-round, especially for river-related recreation in nearby towns such as Alton and East Alton, Illinois. Furthermore, the area around Mel Price is significant for supporting endangered aquatic species, such as lake sturgeon, which can reach 8 feet long, weigh over 200 pounds, and live over 100 years.[10]

In 2015, lake sturgeon were observed spawning in the tailwaters of the dam. This was the first confirmed instance of sturgeon spawning in Missouri in decades. The event spurred scientific and management interest in defining and maintaining suitable hydraulic conditions for sturgeon reproduction, such as flow, timing, temperature, and substrate characteristics.[11] Since then, USACE, in partnership with the Missouri Department of Conservation, U.S. Fish and Wildlife Service and other agencies, has sought to operationalize e-flows tailored to support lake sturgeon spawning. These efforts involve modeling dam gate operations, field monitoring of flow targets, and collaborative outreach and planning under SRP. The Mel Price site entered the Advance phase in 2021 and transitioned to the Implement phase in 2022, marking the initiation of sturgeon-related e-flow actions.

Partners

- USACE St. Louis District
- Illinois Department of Natural Resources
- Missouri Department of Conservation
- Missouri Department of Natural Resources
- River Resources Action Team
- US Fish and Wildlife Service - Endangered Species and Refuges
- TNC and other nongovernmental organizations and private groups

Mel Price has also established e-pool management. Prompted by a unique hydrological event in 2014 that required an extended drawdown period, managers observed a marked return of perennial aquatic vegetation not seen in over two decades.[12] Encouraged by this outcome, USACE and its partners launched a four-year demonstration (2015–2018) that extended low pool conditions from the typical 30–40 days to as long as 90 days during the summer growing season, when hydrologic conditions allowed. Monitoring throughout the demonstration showed increased plant diversity and abundance, particularly among emergent vegetation beneficial to fish, macroinvertebrates, shorebirds, and waterfowl.

4.1.1 Benefits

According to expert interviews, at Mel Price, e-flow and e-pool management actions are being implemented to enhance habitat conditions and support a variety of ecological outcomes in the

[10] The lake sturgeon is a state-endangered fish species in Illinois and Missouri.
[11] https://www.hec.usace.army.mil/sustainablerivers/publications/docs/Mississippi%20-%20Lake%20sturgeon%20spawning%20summary%20-%202022.pdf
[12] Information provided by site experts during the expert elicitation process.

Upper Mississippi River. A central focus of the e-flow strategy is to stimulate natural spawning of lake sturgeon, a state-endangered species, by using e-flows to create suitable hydraulic conditions below the dam during the spring spawning season; these flows are designed to support sturgeon reproduction without the need for artificial stocking. By promoting sturgeon recovery, these actions contribute to natural population dynamics and create educational and public-awareness opportunities, as people visit the area to observe spawning events. Successful natural reproduction could also reduce the likelihood of future listing under the Endangered Species Act, thereby avoiding potential regulatory impacts on navigation. In addition, e-flows provide habitat conditions that align with the reproductive requirements of other native fish species, including blue sucker.

E-pool management actions at Mel Price have further enhanced ecological outcomes by lowering water levels during the growing season, exposing mudflats and creating conditions favorable for the growth of vegetation such as wild millet. This emergent vegetation improves habitat complexity, provides shelter and food for macroinvertebrates and juvenile fish, and enhances fish spawning conditions. These actions contribute to supporting ecosystem services, including the maintenance of life cycles. Additionally, the vegetation and shallow water areas created through e-pool management provide important stopover and feeding habitat for migratory waterfowl using the Mississippi Flyway, supporting cultural ecosystem services such as recreation opportunities.[13] Shorebirds, gulls, and other waterbirds also benefit from these conditions, which enhance aesthetic values and wildlife viewing opportunities. Furthermore, e-pool drawdowns can improve water quality by promoting sediment consolidation and nutrient uptake by vegetation, thereby delivering regulating services related to waste treatment and nutrient cycling. Table 4-1 summarizes the intended benefits of the environmental actions implemented at Mel Price and the associated ecosystem services, as identified by site representatives during expert elicitation interviews.

Table 4-1 Mel Price Intended Benefits and Ecosystem Services

Environmental Action	Intended Benefits	Mapped TEEB Ecosystem Services	
E-flows	Lake Sturgeon / Fisheries	▪ Maintenance of life cycles	Supporting
		▪ Biological control	Regulating
		▪ Information for cognitive development	Cultural
E-pools	Waterfowl / Shorebirds / Fisheries	▪ Maintenance of life cycles	Supporting
		▪ Opportunities for recreation and tourism	Cultural
		▪ Aesthetic information / Inspiration	Cultural
	Wetland Vegetation	▪ Maintenance of soil fertility	Regulating
	Water Quality	▪ Waste treatment	Regulating
		▪ Regulation of water flows / sediment processes	Regulating

To quantify the ecosystem service benefits generated by SRP at Mel Price, we applied the meta-regression coefficients from Equation (2). Model inputs were populated using site-specific variables derived from GIS data and expert survey responses. Benefits were estimated for each

[13] The average vehicle count at Riverlands Migratory Bird Sanctuary has been around 111,000 since 2020, peaking in 2024 with 121,000.

intended benefit that experts reported or expected to result from SRP environmental actions. Table 3-1 summarizes the changes in ecosystem conditions associated with each ecosystem and linked to each intended benefit, as reported by experts. For example, experts indicated that prior to SRP implementation, the ecosystem supporting lake sturgeon at the Mel Price site was degraded. The current condition is considered intermediate and is expected to reach a good condition once maximum annual benefits are achieved, which is projected to occur within 6–10 years from the current year (2024).

Current annual benefits were calculated as the marginal difference between the sum of model-predicted ecosystem service values ($/ha/year) under current (post-SRP action) ecosystem conditions and the predicted values under no-action baseline conditions for each intended benefit. Maximum annual benefit values were calculated as the marginal difference between model-predicted ecosystem service values under the expected ecosystem conditions fostered by SRP, once benefits are fully realized, and the predicted values under no-action baseline conditions. Table 4-2 summarizes the estimated current and maximum potential annual benefits based on these calculations. Current annual value reflects estimated benefits as of 2024, while maximum annual value represents the upper bound of annual benefits assuming full realization of ecological improvements.

Current annual benefits across the intended benefit categories at the Mel Price SRP site are estimated to range from approximately $12,000 for lake sturgeon and fisheries to $231,000 for waterfowl, shorebirds, and fisheries, with additional benefits of about $13,600 associated with wetland vegetation. The estimated maximum annual benefits range from $15,700 for lake sturgeon and fisheries to $237,000 for waterfowl, shorebirds, and fisheries, with wetland vegetation benefits increasing to approximately $17,200 per year. This results in a total potential annual benefit of about $270,000 across all categories. Most of these benefits are attributed to e-pool actions, which affect a relatively large area of 451 hectares, compared to e-flow actions, which cover 24 hectares.

Table 4-2 Annual Benefits from Mel Price SRP by Environmental Action and Intended Benefit

Environmental Action Intended Benefit	Area (ha)	Current Annual Value		Maximum Annual Value	
		$/ha/yr	$/yr	$/ha/yr	$/yr
E-flows					
Lake Sturgeon / Fisheries	24	510	$12,487	$642	$15,713
E-pools					
Waterfowl / Shorebirds / Fisheries[a]	451	$513	$231,419	$527	$237,453
Wetland Vegetation	451	$30	$13,659	$38	$17,187
Water Quality[b]	NA	$0	$0	$0	$0
Total			$257,565		$270,353

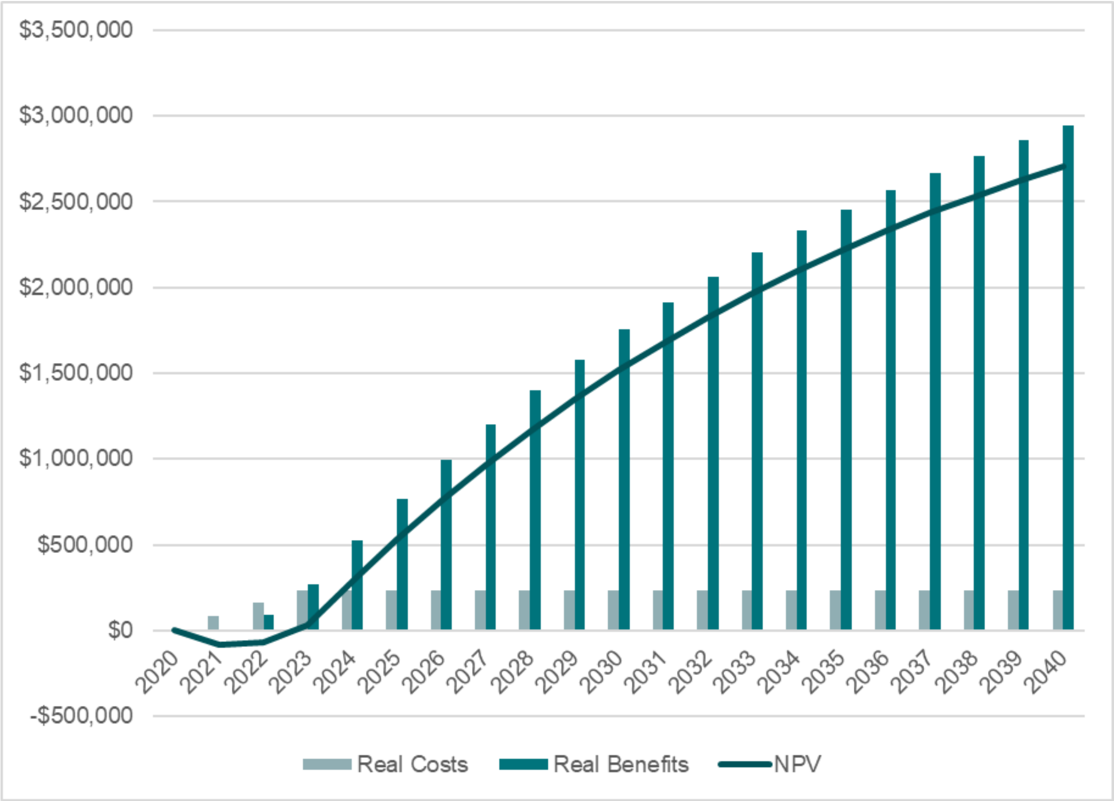
[a] This report assumed improvement of ecosystem services and area from SRP overlap between shorebirds, waterfowl, and fisheries (e-pools), so benefits are grouped to avoid double counting.

[b] While water quality was identified as an intended benefit of the Mel Price SRP, experts indicated that ecosystem condition will remain degraded; therefore, both current and maximum annual benefit values have been set to zero.

4.1.2 Cost–Benefit Analysis

For retrospective benefits, we assumed a linear increase in values from zero at the start of SRP intervention to the current annual value in the present. For prospective benefits, we assumed a linear increase[14] in ecosystem service values from current annual levels to maximum annual values, with the time horizon for full realization based on expert responses, after which annual benefits are held constant. A real discount rate of 7% was applied to both benefits and costs. All benefits and costs were assumed to be fully attributable to environmental actions at the Mel Price project site. Figure 4-1 displays the cumulative present value of benefits and costs, as well as NPV, and Table 4-3 presents the BCR for the Mel Price SRP project from 2020 to 2040. Cumulative discounted benefits increase steadily from the beginning of the program, exceed cumulative investments by 2023, and result in positive net benefits from the third year onward. By 2040, total discounted benefits at Mel Price Lock and Dam are estimated at approximately $2.94 million, compared to $0.24 million in total discounted costs, yielding an NPV of $2.70 million and a BCR of 12.43.

Figure 4-1. Cumulative Present Value Costs and Benefits, and NPV for Mel Price SRP, 2020 to 2040



[14] Assuming a linear increase in benefits over time is a conservative simplification. Site experts indicated that in some cases ecosystem service benefits may begin immediately following implementation rather than accumulating gradually, suggesting that this assumption may underestimate early-period benefits prior to full realization.

Table 4-3 NPV and BCR for Mel Price, 2020–2040

	2020	2025	2030	2035	2040
NPV	$0	$530,201	$1,516,348	$2,215,976	$2,706,484
BCR	0.00	3.24	7.40	10.36	12.43
Costs and benefits calculated using a real discount rate of 7%					

4.1.3 Sensitivity Analysis

To assess the robustness of results, we evaluated the BCR and NPV for the Mel Price SRP under alternative discount rates and cost assumptions. The baseline scenario applied a 7% real discount rate, with additional cases evaluated at 3.25% and 10%. As shown in Table 4-4, results remain strongly positive across all discount rates: the BCR ranges from 15.92 at 3.25% to 10.41 at 10%, while the NPV ranges from $3.53 million to $2.23 million. The modest decline in BCR at higher discount rates reflects the reduced present value of future benefits when greater weight is placed on near-term outcomes.

Recognizing that the baseline assumption of no future costs may underestimate ongoing expenditures, we conducted a sensitivity analysis in which future costs were assumed to equal 50% of total costs incurred to date and were distributed evenly over the remaining analysis period. As shown in Table 4-5, even under this more conservative cost scenario, the NPV remains strongly positive at $2.64 million and the BCR remains close to 10 (9.84), indicating that benefits continue to exceed costs. Overall, the sensitivity analyses confirm the robust economic justification of the Mel Price SRP project, as benefits outweigh costs under all tested discount rate and cost assumptions.

Table 4-4 NPV and BCR in 2040 for Mel Price SRP, by Discount Rate

	Discount Rate		
	3.25%	**7%**	**10%**
NPV	$3,534,827	$2,706,484	$2,227,670
BCR	15.92	12.43	10.41

Table 4-5 NPV and BCR in 2040 for Mel Price SRP, by Future Cost Assumption

	No Future Costs	Future costs (50% of costs to date)
NPV	$2,706,484	$2,644,316
BCR	12.43	9.84

4.2 Case Study 2: Des Moines River

Credit: Stephen J. Dinsmore

Benefit–Cost Highlights for Des Moines River SRP

- $19.9 million in total discounted benefits versus $2.2 million in costs through 2040; NPV of $17.7 million.
- BCR: 8.98 by 2040; every dollar invested yields nearly nine dollars in ecosystem service benefits.
- Benefits exceed costs by 2028, generating positive net benefits from that year onward.
- Maximum potential annual benefits total $3.1 million, primarily from e-pool actions, with e-flows and fisheries contributing an additional $562,000 per year.
- Sensitivity tests confirm BCR remains above 6 under all discount rate scenarios (6.77 at 10%, 12.92 at 3.25%) and above 8 under conservative cost assumptions.

The Des Moines River system in Iowa includes two major USACE reservoirs: Saylorville Lake, located directly upstream of the City of Des Moines, and Lake Red Rock, approximately 50 miles downstream.[15] Operations at these reservoirs influence hydrology along the Des Moines River and ultimately affect the Mississippi River system, including downstream ecological conditions extending to the Gulf of Mexico. In particular, Lake Red Rock helps regulate flows from a watershed that is among the nation's largest contributors to nutrient loading and hypoxia

[15] https://www.mvr.usace.army.mil/Missions/Environmental-Stewardship/Sustainable-Rivers/Des-Moines-River-SRP/

in the Gulf, making its role in nutrient retention and water quality management ecologically significant.

SRP at Des Moines River was launched in 2015 to identify environmental opportunities and implement operational changes that improve riverine and in-reservoir habitat conditions. The program has engaged federal and state agencies, scientists, and conservation organizations to define seasonal flow and pool management strategies that restore key aspects of the natural flow regime.

SRP at the Des Moines River entered the Advance phase for e-pool management in 2015 and transitioned to the Implement phase in 2016. Similarly, e-flows entered the Advance phase in 2015 and transitioned to the Incorporate phase in 2020. E-flow actions on the Des Moines River are typically implemented in the spring to stimulate fish spawning and involve temporarily increasing pool levels within the conservation range and releasing them as flow pulses, guided by real-time biological and hydrologic monitoring. In contrast, e-pool management actions are implemented primarily in the fall to benefit migratory bird species. By manipulating reservoir levels, managers expose or inundate mudflats—particularly in the Delta region of Lake Red Rock—creating high-quality stopover habitat for shorebirds and waterfowl migrating between the Arctic and South America.

Partners

- USACE Rock Island District
- The Nature Conservancy
- Des Moines Water Works
- Iowa Department of Natural Resources
- The University of Iowa-Iowa Geological Survey
- Natural Resources Conservation Service
- Ottumwa Water and Hydro
- Polk County Conservation
- Red Rock Lake Association
- University of Iowa
- U.S. Fish and Wildlife Service
- U.S. Geological Society
- William Penn University

4.2.1 Benefits

E-flows and e-pool management strategies on the Des Moines River have been implemented to restore ecological functions and deliver multiple ecosystem services.[16] E-flows have been developed to support the life histories of native mussels across 142 river miles by increasing spring and fall discharges and enhancing habitat heterogeneity, such as cobble substrates and riparian buffers (Griffen et al., 2024). By fostering mussel population health, these actions provide ecosystem services such as waste treatment, maintenance of life cycles, and maintenance of soil fertility. E-flows have also been used to reduce mortality in shovelnose sturgeon by restoring more natural summer flow patterns and introducing heat-relief pulses to mitigate degraded habitat conditions during periods associated with repeated die-offs. These

[16] Flood Risk Management (FRM) is the primary authorized mission at Des Moines River reservoirs and supersedes environmental stewardship activities, including SRP. Site representatives noted that while SRP practices are ecologically preferred when feasible, their implementation is constrained during periods when FRM objectives govern operation.

management considerations are particularly important given that sustained low outflows, combined with high temperatures and low dissolved oxygen, have caused large fish kills in the Des Moines River, including shovelnose sturgeon.[17]

In addition, e-flows mimic natural spring flood pulses that support the spawning and rearing of native fish species, including Sciaenidae and Clupeidae.[18] These managed discharges enhance fish reproductive success by influencing the density of larval fish populations and by flushing zooplankton from the reservoir into downstream reaches, improving foraging conditions for early life stages of fish. This process supports ecosystem services such as the maintenance of life cycles.

E-pool management actions at Lake Red Rock further support ecological goals by enhancing habitat for a range of species. One focus is support for herpetofauna, with pilot studies documenting a variety of amphibians and reptiles, such as bullfrogs, spring peepers, and snapping turtles, that benefit from managed water levels creating stable overwintering and breeding habitats (Thostenson et al., 2024). These actions contribute to supporting ecosystem services related to the maintenance of life cycles, as well as cultural values associated with biodiversity preservation. Shorebirds and other waterbirds also benefit from water level drawdowns, which expose mudflats and create diverse foraging environments during fall migration.[19] These drawdowns have been linked to increased species richness and greater use of the reservoir by migratory bird guilds, particularly shorebirds. Management of the Lake Red Rock delta during drawdowns promotes abundant invertebrate communities in newly exposed mudflats, which attract shorebirds and can extend their stopover duration, potentially influencing migration timing and distance.[20] Subsequent vegetation growth, flowering, and seed production support migrating waterfowl and provide additional benefits for pollinators when fall pool levels rise. Collectively, these outcomes generate a suite of supporting and cultural ecosystem services, including existence and bequest values.

Vegetation management is another intended benefit of e-pool operations. Seasonal drawdowns promote the growth of desirable annual moist-soil plants, increasing vegetation cover and diversity while enhancing food resources for migratory birds and monarch butterflies during their southward migration. In addition, both e-flows and e-pools contribute to improved water quality. Seasonal drawdowns help reduce nitrate and phosphorus levels in the reservoir through natural uptake processes. Table 4-6 lists the intended benefits of the environmental actions implemented on the Des Moines River, along with the corresponding ecosystem services, as identified by site representatives during expert elicitation interviews.

[17] Information based on interviews with Des Moines River site representatives.
[18] https://ewn.erdc.dren.mil/wp-content/uploads/2023/04/06-2023_Feb_DownstreamFisheries_Griffen.pdf
[19] https://www.hec.usace.army.mil/sustainablerivers/publications/docs/Des%20Moines%20-%20Waterbird%20and%20aquatic%20invertebrate%20responses%20to%20reservoir%20drawdowns%20-%20Field%20report%20-%202023.pdf
[20] https://faculty.sites.iastate.edu/cootjr/project/bird-and-vegetation-responses-sustainable-rivers-program-iowa

Table 4-6 Des Moines Intended Benefits and Ecosystem Services

Environmental Action	Intended Benefits	Mapped TEEB Ecosystem Services	
E-Flows	Mussels	▪ Waste treatment	Regulating
		▪ Maintenance of life cycles	Supporting
		▪ Maintenance of soil fertility	Regulating
	Fisheries / Sturgeon	▪ Maintenance of life cycles	Supporting
		▪ Opportunities for recreation and tourism	Cultural
E-Pools	Herptiles	▪ Maintenance of life cycles	Supporting
		▪ Existence and bequest values	Cultural
	Shorebirds	▪ Maintenance of life cycles	Supporting
		▪ Existence and bequest values	Cultural
	Water Quality	▪ Waste treatment (water quality)	Regulating
	Wetland Vegetation	▪ Maintenance of soil fertility	Regulating
		▪ Maintenance of genetic diversity	Supporting

To quantify the ecosystem service benefits generated by SRP on the Des Moines River, we applied the estimated parameters from the meta-regression model (Equation 1) using site-specific inputs derived from GIS data and expert responses (see Table 3-1). Values were estimated for intended benefit categories in which ecological improvements were defined based on expert input, specifically for mussel, sturgeon, and other fish habitat associated with e-flows, as well as herptile habitat, shorebird habitat, and water quality associated with e-pools. Current and maximum annual benefits were calculated as the marginal difference between model-predicted values under existing conditions and baseline (no-action) conditions. Table 4-7 summarizes the estimated annual benefits.

Current annual benefits for each intended benefit category at the Des Moines SRP site are estimated at $0, as experts did not report observable differences between current and baseline conditions for any category. However, experts noted that ecological conditions in the reservoirs and river are expected to improve to good or intermediate condition once the practice is fully implemented. Maximum potential annual benefits are estimated to range from approximately $116,000 to $2.0 million per year, totaling about $3.1 million annually across all categories. The largest share of these benefits is associated with herptile-related intended benefits, which affect 6,281 hectares and are projected to generate up to $2.0 million in annual value once ecological improvements are fully realized. E-flow–related fisheries benefits also contribute substantially, together accounting for more than $562,000 in potential annual value.

Table 4-7 Annual Benefits from Des Moines SRP by Environmental Action and Intended Benefit

Environmental Action Intended Benefit	Area (ha)	Current Annual Value[a]		Maximum Annual Value	
		$/ha/yr	$/yr	$/ha/yr	$/yr
E-flows					
Mussels	695	$0	$0	$437	$305,365
Fisheries/Sturgeon	695	$0	$0	$370	$257,250
E-pools					
Herptiles	6,281	$0	$0	$319	$2,003,235
Shorebirds	1,214	$0	$0	$403	$489,189
Water Quality	1,298	$0	$0	$89	$116,171
Wetland Vegetation[b]	NA	$0	$0	$0	$0
Total			$0		$3,171,210

[a] Current annual values are zero because, according to site experts, ecosystem conditions have not improved from their baseline state despite approximately 10 years of interventions. This suggests that no measurable ecological changes have yet occurred for the intended benefits, and therefore, no current ecosystem service value can be attributed. It is assumed that benefits will begin to accrue only when observable improvements in ecosystem condition occur beyond the 10-year mark.

[b] While wetland vegetation was identified as an intended benefit of the Des Moines SRP, experts did not expect significant improvements to ecosystem condition; although benefits are possible, we do not include in benefit evaluation and the current and maximum annual values were set to zero.

4.2.2 Cost–Benefit Analysis

The CBA applies a 7% real discount rate to both costs and projected benefits. All benefits are assumed to begin accruing in 2025 and continue through 2040, consistent with expected implementation timelines and ecological lag effects. Figure 4-2 displays the cumulative present value of benefits and costs and the resulting NPV, while Table 4-8 presents the BCR for the Des Moines SRP from 2020 to 2040.

The analysis estimates an NPV of approximately $17.7 million and a BCR of 8.98 by 2040. Benefits begin accruing in the future because current and baseline conditions are equivalent for each intended benefit, and no positive benefits are observed immediately following implementation. Benefits begin to exceed costs around 2028, resulting in positive net benefits from that year onward. By 2040, total discounted benefits reach approximately $19.9 million, compared to $2.2 million in total discounted costs, yielding an NPV of about $17.7 million. The BCR increases gradually over time after 2024 as costs plateau and benefits continue to accrue. At the Des Moines River, the final BCR value of 8.98 by 2040 indicates that every $1 invested by SRP generates nearly $9 in quantified ecosystem service benefits.

Figure 4-2. Cumulative Present Value Costs and Benefits and NPV for Des Moines River SRP, 2020 to 2040.

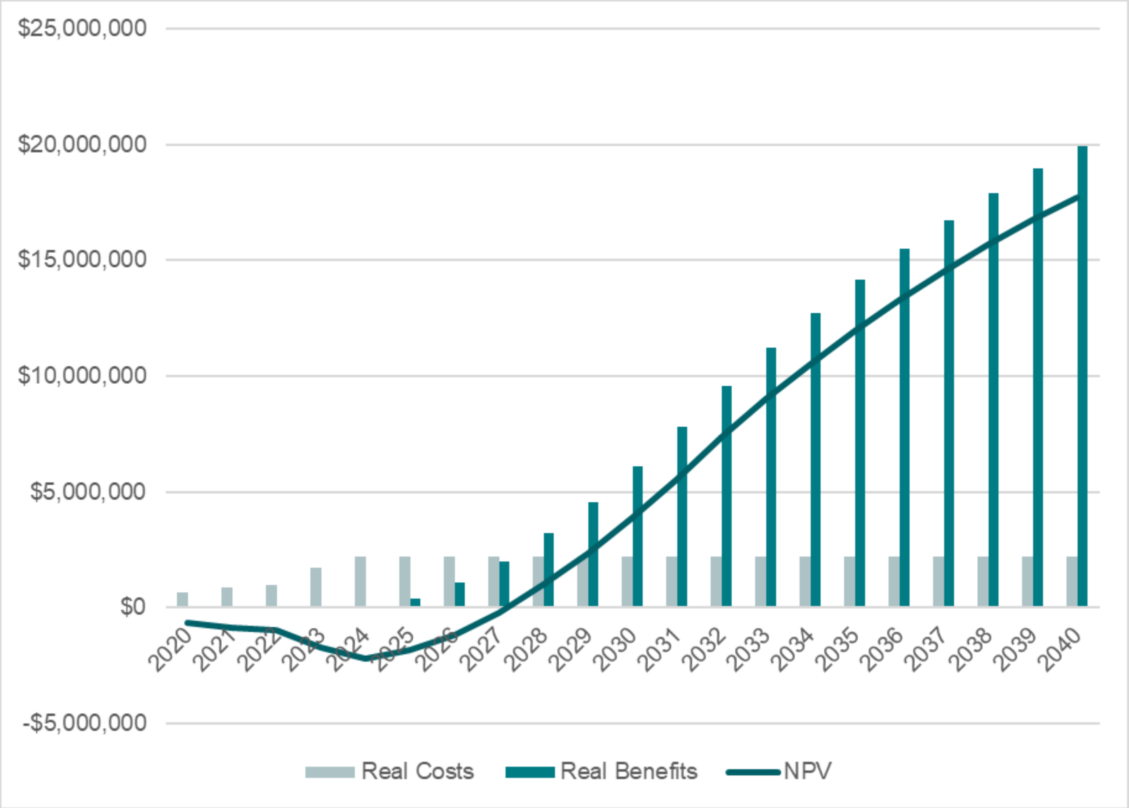


Table 4-8 NPV and BCR for Des Moines River, 2015–2040

	2015	2020	2025	2030	2035	2040
NPV	-$29,116	-$646,183	-$1,851,556	$3,894,463	$11,951,135	$17,722,000
BCR	0.00	0.00	0.17	2.75	6.38	8.98
Costs and benefits calculated using a real discount rate of 7%						

4.2.3 Sensitivity Analysis

To assess the robustness of results, we evaluated the NPV and BCR for the Des Moines River SRP under alternative discount rate and cost assumptions. The baseline scenario applied a 7% real discount rate, with additional cases evaluated at 3.25% and 10%. As shown in Table 4-9, results remain positive across all discount rates: the BCR ranges from 12.92 at 3.25% to 6.77 at 10%, while the NPV ranges from $26.47 million to $12.81 million, respectively. The decline in BCR at higher discount rates reflects the reduced present value of future benefits when greater emphasis is placed on near-term outcomes.

We also conducted a sensitivity analysis of costs in which future costs were assumed to equal 50% of total costs incurred to date and were distributed evenly over the remaining analysis period. As shown in Table 4-10, even under this more conservative cost scenario, the NPV remains positive at $17.14 million and the BCR remains above 7, indicating that benefits continue to exceed costs by a substantial margin. Overall, the sensitivity analyses confirm the robust economic justification of the Des Moines River SRP project, as benefits outweigh costs under all tested discount rate and cost assumptions.

Table 4-9 Cumulative NPV and BCR in 2040 for Des Moines River SRP, by Discount Rate

	Discount Rate		
	3.25%	**7%**	**10%**
NPV	$26,473,437	$17,722,000	$12,809,823
BCR	12.92	8.98	6.77

Table 4-10 NPV and BCR in 2040 for Des Moines SRP, by Future Cost Assumption

	No Future Costs	Future costs (50% of costs to date)
NPV	$17,722,000	$17,140,203
BCR	8.98	7.12

4.3 Case Study 3: Caddo Lake

Credit: Fauna Creative

Benefit–Cost Highlights for Caddo Lake SRP

- $3.22 million in total discounted benefits versus $0.36 million in costs through 2040; NPV of $2.86 million.
- BCR: 7.89 by 2040; every dollar invested yields more than seven dollars in ecosystem service benefits.
- Annual benefits total $89,000, driven by fisheries ($71,700) and water quality ($17,500) improvements, with maximum potential benefits reaching $750,000 per year as flood protection ($382,000) and floodplain connectivity ($276,000) gains are realized.
- Sensitivity tests confirm robust performance: BCR ranges from 10.56 at 3.25% to 6.42 at 10%, and remains above 7 under conservative cost assumptions.

The Caddo Lake/Big Cypress Bayou SRP project centers on Caddo Lake, located on the Texas–Louisiana border. The watershed spans approximately 2,970 square miles, about one-third of which is regulated by Lake O' the Pines and other upstream reservoirs.[21] The Caddo Lake watershed features extensive bald cypress swamps, bottomland hardwood forests, and diverse aquatic habitats. Recognized as a Ramsar Wetland of International Importance, Caddo Lake supports high biodiversity, including species such as paddlefish, bluehead shiners, and

[21] https://www.hec.usace.army.mil/sustainablerivers/sites/bigcypress/

freshwater mussels. The lake also contributes to the economies of nearby rural communities, particularly in towns such as Uncertain, Texas, through tourism-related activities including boating, birdwatching, hunting, and fishing.

A key hydrological control point in the system is Lake O' the Pines, a USACE reservoir. The dam, associated infrastructure, and all lake project lands are federally owned and administered by the USACE Fort Worth District. The dam's primary function is flood risk management, with secondary roles in water supply, recreation, and fish and wildlife conservation.

Partners

- USACE Fort Worth District
- The Nature Conservancy
- Caddo Lake Institute
- Northeast Texas Municipal Water District

USACE, in partnership with TNC and the Caddo Lake Institute, launched an SRP environmental action initiative in 2004 to address ecological degradation. The goal was to restore natural hydrologic variability through the development and implementation of e-flow recommendations. Early recommendations were based on historical hydrologic analyses, particularly the 1.5-year recurrence interval flow (approximately 6,000 cfs[22]), which was used as a surrogate for bankfull flow—the stage at which a stream or river conveys the maximum discharge within its channel before spilling onto the floodplain. This initial guidance evolved through a series of stakeholder workshops held in 2005, 2008, and 2011 and was supported by empirical data from the U.S. Geological Survey. Research confirmed that flows between 1,500 and 2,500 cfs were effective in restoring riparian and wetland connectivity near Jefferson, Texas.[23] These flow prescriptions have been implemented since 2012, when SRP transitioned from the Advance phase to the Implement phase.

4.3.1 Benefits

According to expert interviews, e-flow and e-pool actions at Caddo Lake have been implemented to restore hydrologic and ecological processes in Big Cypress Bayou and the broader lake system. E-flows in Big Cypress Bayou are designed to enhance fish habitat and populations, particularly for species such as American paddlefish, by supporting critical life stages.[24, 25] These actions also enhance recreational opportunities, including fishing, waterfowl hunting, and tourism, which are vital to the local economy in nearby communities. Additionally, e-flows improve river–floodplain connectivity by providing periodic inundation essential for maintaining cypress swamps and floodplain forests. Monitoring has demonstrated that, in the absence of high-flow pulses, higher-elevation floodplain forests experience increased mortality and reduced regeneration, underscoring the necessity of environmental flows for long-term floodplain health (Smith et al., 2019). This reconnection supports fish communities, particularly

[22] Cubic feet per second.
[23] https://www.hec.usace.army.mil/sustainablerivers/publications/docs/Big%20Cypress%20-%20Summary%20report%20on%20high%20flow%20pulses.pdf
[24] https://www.hec.usace.army.mil/sustainablerivers/publications/docs/Big%20Cypress%20-%20Paddlefish%20reintroduction%20assessment.pdf
[25] Flow-ecology workshop Big Cypress Bayou - Caddo Lake

paddlefish, and improves the ecological condition of riparian habitats. In doing so, it provides regulating services such as erosion prevention and water purification, as well as supporting services related to forest health and regeneration.

Flow operations at upstream Lake O' the Pines are used to minimize flood risk at Caddo Lake downstream, although their effectiveness may be limited during high inflow events from the broader watershed. Monitoring of soil moisture across different plant communities indicates that pulse releases associated with e-flows have increased soil moisture levels. These releases also help improve water quality by enhancing waste treatment functions, particularly during low-flow periods when nutrient concentrations and water temperatures tend to rise. By improving water quality, these operations contribute directly to water purification ecosystem services. Table 4-11 lists the intended benefits of the environmental actions implemented at Caddo Lake, along with the corresponding ecosystem services, as identified by site representatives during expert elicitation interviews.

To quantify the ecosystem service benefits generated by SRP at Caddo Lake, we applied estimated parameters from the meta-regression model (Equation 1) using site-specific inputs derived from GIS data and expert survey responses (see Table 3-1). Benefits were estimated for each intended benefit based on the corresponding ecosystem service categories listed in Table 4-11.[26]

Table 4-11 Caddo Lake Intended Benefits and Ecosystem Services

Environmental Action		Intended Benefits	Mapped TEEB Ecosystem Services
E-Flows (Big Cypress Bayou)	Fisheries	▪ Maintenance of life cycles	Supporting
		▪ Opportunities for recreation and tourism	Cultural
	Floodplain Connectivity	▪ Erosion prevention	Regulating
		▪ Water purification	Regulating
		▪ Maintenance of life cycles (proxy for Forest Health)	Supporting
E-Pools (Caddo Lake)	Water Quality	▪ Waste treatment	Regulating
	Flood protection	▪ Moderation of extreme events	Regulating
		▪ Erosion prevention	Regulating

Current and maximum annual benefits were calculated as the marginal difference between model-predicted ecosystem service values under current conditions and baseline (no-action) conditions. At Caddo Lake, experts indicated that current ecological conditions for some benefit categories are relatively close to the maximum expected improvements, resulting in similar current and maximum annual values for those benefits. Table 4-12 summarizes the estimated annual benefits from the SRP.

[26] While floodplain connectivity and flood protection were identified as intended benefits, site experts did not expect significant improvements in condition due to SRP over the next 20 years, so these benefits are not included.

Current annual benefits at the Caddo Lake SRP site total approximately $89,000 per year, driven primarily by fisheries benefits ($71,700 per year) and water quality benefits ($17,500 per year). Maximum potential annual benefits are projected to reach nearly $750,000 per year, reflecting additional future benefits from flood protection ($382,000 per year) and floodplain connectivity ($276,000 per year) associated with e-flow and e-pool actions across the 809-hectare project area.

4.3.2 Cost–Benefit Analysis

The CBA applies a 7% real discount rate to both costs and projected benefits, all of which are assumed to be fully attributable to SRP actions at the Caddo Lake project site. For benefits, the analysis assumes a linear increase from zero at the start of SRP activities to current annual ecosystem service values, followed by a constant annual stream of benefits thereafter.

Figure 4-3 displays the cumulative present value of discounted benefits and costs and the resulting NPV, while Table 4-13 presents the BCR for the Caddo Lake SRP from 2010 to 2040. Cumulative discounted benefits increase steadily from the initiation of the program and exceed cumulative discounted costs around 2015, resulting in positive net benefits from that point forward.

By 2040, total discounted benefits at Caddo Lake are estimated at approximately $3.22 million, compared to $0.36 million in total discounted costs, yielding an NPV of $2.86 million. The resulting benefit–cost ratio of 7.89 indicates that each dollar invested in the Caddo Lake SRP generates nearly $8 in quantified ecosystem service benefits over the analysis period.

Table 4-12 Annual Benefits from Caddo Lake SRP by Environmental Action and Intended Benefit

Environmental Action Intended Benefit	Area (ha)	Current Annual Value		Maximum Annual Value	
		$/ha/yr	**$/yr**	**$/ha/yr**	**$/yr**
E-flows					
Fisheries	809	$89	$71,722	$89	$71,722
Floodplain Connectivity	809	0	0	$341	$276,065
E-pools					
Water Quality	809	$22	$17,483	$22	$17,483
Flood Protection	809	0	0	$472	$382,045
Total			$89,205		$747,315

Figure 4-3. Present Value Costs, Present Value Benefits, NPV, and BCR for Caddo Lake SRP, 2020 to 2040

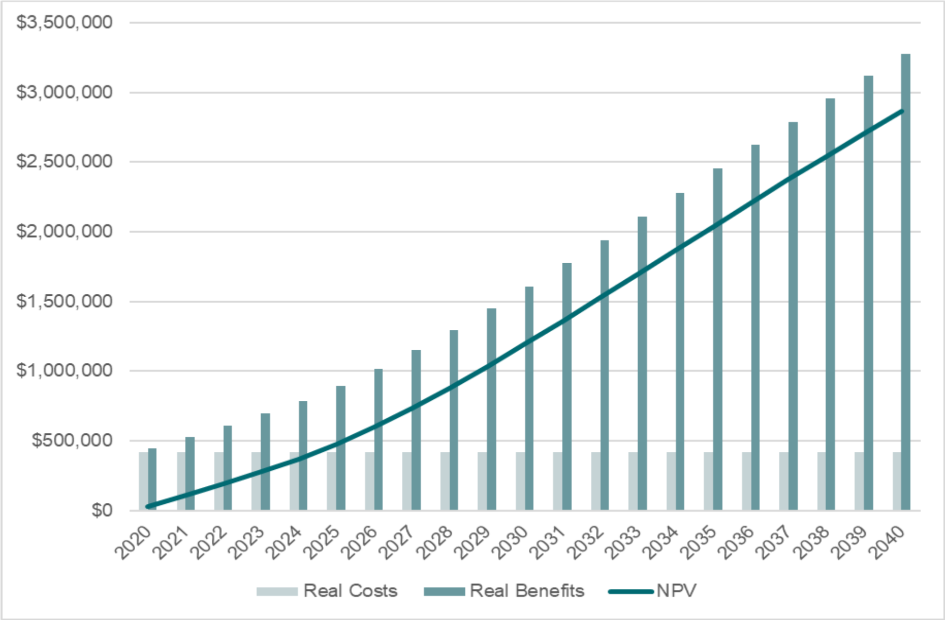


Table 4-13 NPV and BCR for Caddo Lake, 2010–2040

	2010	2015	2020	2025	2030	2035	2040
NPV	-$43,156	-$96,509	$31,081	$476,105	$1,193,100	$2,036,199	$2,862,254
BCR	0.00	0.57	1.07	2.15	3.87	5.90	7.89
Costs and benefits are calculated using a real discount rate of 7%.							

4.3.3 Sensitivity Analysis

To assess the robustness of results, we evaluated the NPV and BCR for Caddo Lake under alternative discount rate and cost assumptions. The baseline scenario applied a 7% real discount rate, with additional cases evaluated at 3.25% and 10%. As shown in Table 4-11, results remain positive across all discount rates: the BCR ranges from 10.56 at 3.25% to 6.42 at 10%, while the NPV ranges from $3.97 million to $2.25 million. Consistent with analyses at other sites, we also conducted a sensitivity analysis of costs in which future costs were assumed to equal 50% of total costs incurred to date and were distributed evenly over the remaining analysis period. As shown in Table 4-12, even under this more conservative cost scenario, the NPV remains strongly positive at $2.77 million and the BCR remains stable at 7.65, indicating that benefits continue to exceed costs by a substantial margin. Overall, the sensitivity analyses indicate that benefits outweigh costs under all tested discount rate and cost assumptions.

Table 4-14 Cumulative NPV and BCR in 2040 for Caddo Lake SRP, by Discount Rate

	Discount Rate		
	3.25%	7%	10%
NPV	$3,969,152	$2,862,254	$2,250,492
BCR	10.56	7.89	6.42

Table 4-15 NPV and BCR in 2040 for Caddo Lake SRP, by Future Cost Assumption

	No Future Costs	Future costs (50% of costs to date)
NPV	$2,862,254	$2,770,999
BCR	7.89	7.65

4.4 Case Study 4: Green River

Credit: Jim Howe

Benefit–Cost Highlights for Green River

- $37.8 million in total discounted benefits through 2040.
- Annual benefits currently total $2.11 million, with the majority derived from e-flow action—$1.31 million from fisheries and $298,000 from mussel habitat restoration across 4,989 hectares.
- E-pool actions provide an additional $502,000 per year from recreation ($211,000) and habitat enhancement ($291,000) across 1,331 hectares.
- Benefits are projected to reach $2.65 million annually by 2040.

Green River Lake and Dam is located in south-central Kentucky, approximately 90 miles south-southeast of Louisville. The lake spans Taylor, Adair, and Casey counties, with the dam situated at river mile 305.7 on the Green River. Constructed between 1964 and 1969, the project was originally designed as a multipurpose facility, with flood risk management as its primary function. The dam consists of an earth- and rock-fill structure with multilevel release capabilities that allow for control of downstream water temperatures.

Green River Lake also provides a wide range of recreational opportunities, including camping, fishing, boating, hiking, swimming, and sightseeing. Ecologically, the Green River is recognized as one of the most biologically diverse rivers in the U.S., supporting more than 60 mussel species, 152 fish species, numerous endemic species, and multiple cave systems hydrologically connected to the river.[27]

Because of the river's exceptional biodiversity, USACE and TNC implemented a reoperation plan in 2002 to create more natural flow and temperature regimes by modifying water releases from Green River Dam. After four years of altered operations, scientists documented successful reproduction among several mussel species, indicating a positive trajectory for long-term recovery (Meffert, 2010).

Partners

- USACE Louisville District
- The Nature Conservancy
- U.S. Fish and Wildlife Service
- Kentucky Department of Fish and Wildlife Resources
- Mammoth Cave National Park
- Kentucky Waterways Alliance

The environmental actions implemented included both e-flows and e-pool management. For e-flows, the spring filling schedule was extended, and the fall drawdown schedule was modified to reduce cold-water releases and better replicate natural flow regimes. For e-pools, the winter pool level was raised from 664 to 668 feet to improve water quality and more closely mimic natural hydrologic conditions. Collectively, these changes improved downstream water quality, reduced turbidity, and enhanced aquatic habitats. In addition, modifications to release structures enabled warmer water discharges during the spring, further supporting aquatic ecosystems.

4.4.1 Benefits

According to expert interviews, a central focus of the e-flow strategy is to sustain the life histories of native mussel species by providing flow regimes and water levels that enhance habitat stability and host–fish interactions. These conditions are particularly important given the river's high biodiversity, which includes more than 60 mussel species. Site representatives noted that ecological observations, while largely anecdotal, suggest improved or stabilized mussel populations, along with broader improvements in aquatic habitats and downstream ecological conditions. The e-flow strategy also supports fish populations by aligning water releases with spawning, rearing, and foraging needs. Fish species that spawn during the fall, in particular, have shown evidence of stable or improving populations since the project began. Collectively, these outcomes contribute to supporting ecosystem services related to the maintenance of life cycles, helping to ensure that critical ecological functions are sustained across the river system.

E-pool management has further expanded the range of ecological and cultural benefits by extending the summer pool period, thereby prolonging the recreational season for boating, fishing, and other lake-based activities well into October. This extension has increased opportunities for tourism and recreation, delivering cultural ecosystem services associated with recreational use.

[27] https://www.hec.usace.army.mil/sustainablerivers/sites/green/

In addition, e-pool management actions have improved physical habitat conditions by moderating water releases to prevent sudden and prolonged discharges of cold water that can stress downstream habitats. These actions have enhanced mussel breeding conditions and helped restore more natural flow regimes, thereby reducing ecological stress. As a result, they provide regulating ecosystem services such as improved waste treatment and regulation of water flows. Table 4-16 summarizes the intended benefits of the environmental actions implemented at the Green River, along with the corresponding ecosystem services, as identified by site representatives during expert elicitation interviews.

To quantify the ecosystem service benefits generated by SRP at the Green River, we applied estimated parameters from the meta-regression model (Equation 1) using site-specific inputs derived from GIS data and expert survey responses (see Table 3-1). Benefits were estimated for each intended benefit based on the corresponding ecosystem service categories listed in Table 4-16.

Table 4-16 Green River Intended Benefits and Ecosystem Services

Environmental Action	Intended Benefits	Mapped TEEB Ecosystem Services	
E-flows	Mussels	▪ Waste treatment	Regulating
		▪ Maintenance of life cycles	Supporting
		▪ Maintenance of soil fertility	Regulating
	Fisheries	▪ Maintenance of life cycles	Supporting
E-pools	Recreation	▪ Opportunities for recreation and tourism	Cultural
	Habitat Enhancement	▪ Waste treatment	Regulating
		▪ Regulation of water flows	Regulating

Current and maximum annual benefits were calculated as the marginal difference between model-predicted ecosystem service values under current conditions and baseline (no-action) conditions. The results are summarized in Table 4-17.

Table 4-17 Annual Benefits from Green River SRP by Environmental Action and Intended Benefit

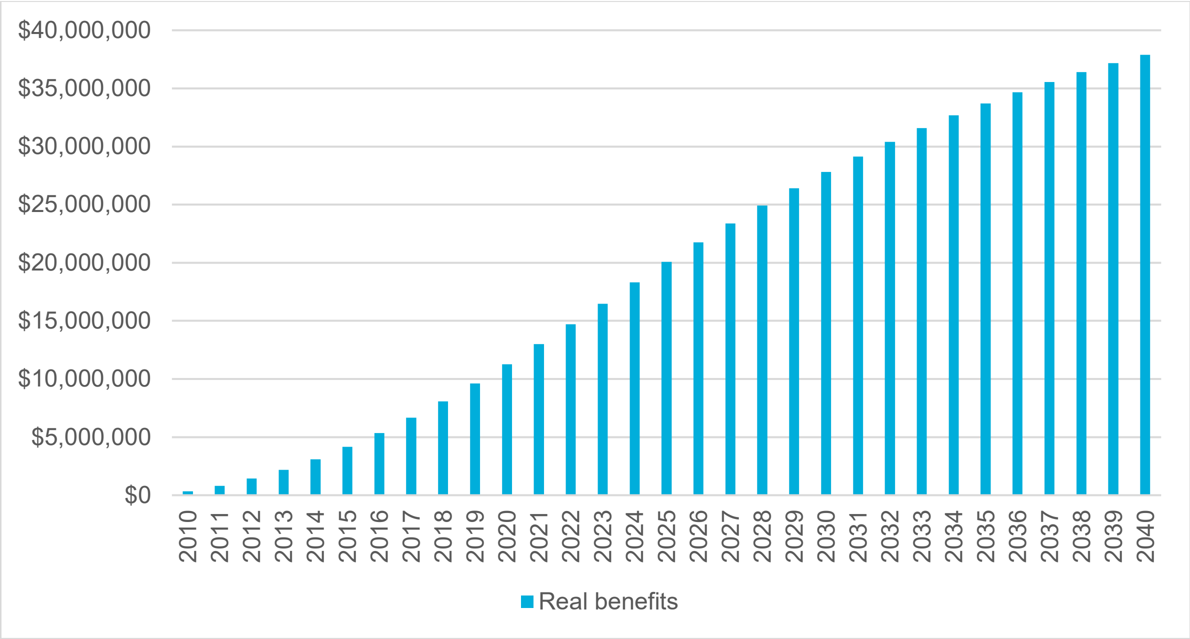
Environmental Action Intended Benefit	Area (ha)	Current Annual Value		Maximum Annual Value	
		$/ha/yr	**$/yr**	**$/ha/yr**	**$/yr**
E-flows					
Fisheries	4,989	$263	$1,313,037	$331	$1,652,202
Mussels	4,989	$60	$298,209	$75	$375,239
E-pools					
Recreation	1,331	$159	$211,162	$194	$257,649
Habitat Enhancement	1,331	$219	$291,460	$276	$366,746
Total			$2,113,869		$2,651,836

SRP-recommended actions at the Green River are currently generating approximately $2.11 million per year in total benefits, with the majority derived from e-flow actions. These benefits include an estimated $1.31 million per year from fisheries and $298,000 per year from mussel habitat restoration across approximately 4,989 hectares. Additional benefits are associated with e-pool actions, which generate about $211,000 per year from recreation and $291,000 per year from habitat enhancement across 1,331 hectares. Annual benefits are expected to continue increasing as habitat conditions improve, reaching approximately $2.65 million per year by 2040 as a result of SRP implementation.

4.4.2 Cost–Benefit Analysis

Although reoperation planning for the Green River began in 2002, data on implementation costs are only available from 2010 onward. Because a substantial portion of program costs cannot be captured, we present only the net present benefits associated with the SRP, rather than the BCR and NPV. A 7% real discount rate was applied to benefits, which are assumed to be fully attributable to the SRP. Figure 4-4 shows cumulative discounted benefits from 2010 to 2040. The SRP has generated roughly $20 million in real benefits since 2010, and as ecosystem conditions continue to improve, benefits are expected to exceed $37 million in real value by 2040.

Figure 4-4 Cumulative Discounted Benefits for Green River, 2010 to 2040



4.4.3 Sensitivity Analysis

At a 3.25% discount rate, real benefits are expected to exceed $44.8 million by 2040. Under a more conservative assumption using a 10% discount rate, real benefits are projected to be approximately $30.4 million. This compares with $37.8 million in expected benefits calculated using a 7% discount rate.

5. Aggregation of Impacts

Sustainable River Program Distribution
Credit: USACE[28]

Based on program budget information and documentation of acres and river miles affected by SRP actions, as reported in the SRP Metrics Framework (USACE & TNC, 2025), we calculated an order-of-magnitude estimate of the returns on program investments to date, including the four case study sites. For historical costs, we aggregated the total annual budgets reported for all other sites in the program from 2010 to 2024 and applied an inflation adjustment based on the Consumer Price Index (CPI).

To calculate benefits for the additional sites, we applied the estimated parameters from the regression model (Equation 1) using a set of assumptions for the independent variables. Areas affected by site and by action purpose were converted to hectares. To convert river miles to hectares, we calculated the average river width using measurements from three randomly selected points along the SRP areas of impact for each river.[29] We then assigned a single ecosystem service category to each affected action purpose to generate benefits using the

[28] https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/sustainable-rivers-project/

[29] Because the meta-analysis expresses ecosystem service values on a per-hectare basis, we calculated river areas as the product of length and mean width to ensure consistency with the valuation framework. This area-based approximation provides a practical and transparent method for comparing benefits across sites and ecosystem types within the same analytical units ($/ha/yr).

regression model. We also assumed that the biome for all sites is rivers and lakes and applied the average mean species abundance and population density values derived from the four case study sites. Because expert information on ecological conditions was not available for the additional sites, we evaluated the following two scenarios:

- **Scenario 1:** For each site and action purpose, ecological conditions were assumed to be degraded prior to SRP implementation, intermediate under current conditions, and good once benefits are fully realized. Full realization of benefits was assumed to occur eight years from the present for each site.
- **Scenario 2:** For each site and action purpose, ecological conditions were assumed to be degraded prior to SRP implementation, intermediate under current conditions, and to remain intermediate once benefits are fully realized.

Table 5-1 presents the assumed characteristics for each site and scenario using this approach.

To calculate benefits over time, we estimated the marginal difference in site value between a no-action scenario, corresponding to baseline conditions over time, and a counterfactual scenario, corresponding to improved conditions over time, with annual benefits scaled linearly until they reach their maximum. For historical benefits, we applied an inflation adjustment based on the CPI, and for projected benefits, we applied a 7% real discount rate. Figure 5-1 presents the cumulative present value of costs and benefits, as well as NPV, for each scenario, and Table 5-2 reports the BCR estimated under this approach for each scenario.

Figure 5-1. Present Value Costs, Present Value Benefits, NPV, and BCR for Selected SRP Sites, 2020 to 2040

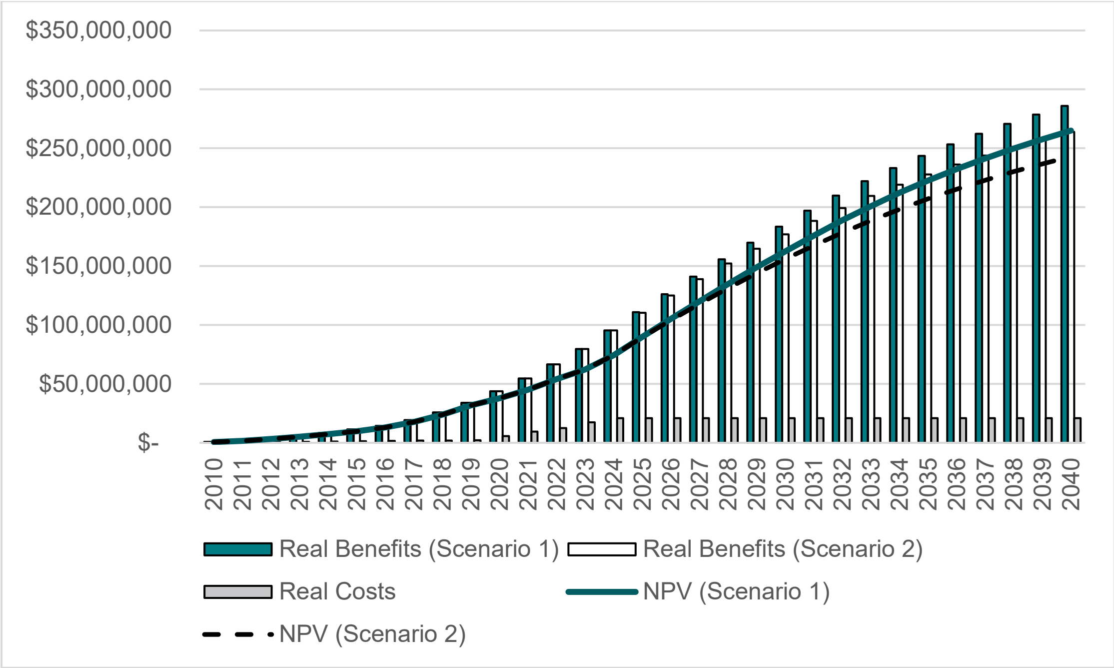


Table 5-1 Intended Benefits and Assumed Site Characteristics Across SRP for Aggregate Program Benefits Analysis

Site	Start Year	Intended Benefit	Area (ha)	Relevant Site Conditions				Years Until Maximized Benefits
				Baseline	Current	Maximum		
						Scenario 1	*Scenario 2*	
Barren River	2012	Floodplain	830	Degraded	Intermediate	Good	Intermediate	8
Bill Williams River	2006	Fisheries	716	Degraded	Intermediate	Good	Intermediate	8
		Geo. Process	716	Degraded	Intermediate	Good	Intermediate	8
		Veg. Riparian	716	Degraded	Intermediate	Good	Intermediate	8
		Benthics	716	Degraded	Intermediate	Good	Intermediate	8
Cape Fear River	2020	Fisheries	2,969	Degraded	Intermediate	Good	Intermediate	8
		Fish Pass.	4,443	Degraded	Intermediate	Good	Intermediate	8
		Habitat Structures	4,443	Degraded	Intermediate	Good	Intermediate	8
Cossatot River	2023	Mussels	1,697	Degraded	Intermediate	Good	Intermediate	8
Iowa River - E-Flows	2023	Fisheries	3,586	Degraded	Intermediate	Good	Intermediate	8
		Mussels	1,300	Degraded	Intermediate	Good	Intermediate	8
		Herptiles	2,286	Degraded	Intermediate	Good	Intermediate	8
		Temperature Management	1,300	Degraded	Intermediate	Good	Intermediate	8
		Shorebirds, Gulls, Other Water Birds	2,286	Degraded	Intermediate	Good	Intermediate	8
Roanoke River	2016	Fisheries	3,745	Degraded	Intermediate	Good	Intermediate	8
		Geo. Process	3,745	Degraded	Intermediate	Good	Intermediate	8
		Floodplain	53,767	Degraded	Intermediate	Good	Intermediate	8
Salt River	2023	Fisheries	1,476	Degraded	Intermediate	Good	Intermediate	8
Upper Ohio River	2023	Fisheries	4,731	Degraded	Intermediate	Good	Intermediate	8
		Mussels	4,731	Degraded	Intermediate	Good	Intermediate	8
		Geo. Process	4,731	Degraded	Intermediate	Good	Intermediate	8
		Herptiles	4,731	Degraded	Intermediate	Good	Intermediate	8
Willamette River	2008	Fisheries	12,284	Degraded	Intermediate	Good	Intermediate	8
		Geo. Process	12,284	Degraded	Intermediate	Good	Intermediate	8
		Veg. Riparian	12,284	Degraded	Intermediate	Good	Intermediate	8
Bois de Sioux River	2023	Shorebirds, Gulls, Other Water Birds	2,428	Degraded	Intermediate	Good	Intermediate	8
Kaskaskia River*	2021	Wetlands Veg.	599	Degraded	Intermediate	Good	Intermediate	8
Mel Price	2021	Lake Sturgeon/ Fisheries	24	Degraded	Intermediate	Good	Good	6 to 10
		Waterfowl	451	Degraded	Good	Good	Good	6 to 10
		Shorebirds	451	Degraded	Intermediate	Good	Good	11 to 20
		Fisheries	451	Degraded	Intermediate	Good	Good	11 to 20
		Wetland Vegetation	451	Degraded	Intermediate	Good	Good	6 to 10
		Water Quality	NA	Degraded	Degraded	Degraded	Degraded	NA
Des Moines	2015	Mussels	695	Degraded	Degraded	Intermediate	Intermediate	6 to 10
		Fisheries/ Sturgeon	695	Degraded	Degraded	Good	Good	6 to 10
		Herptiles	6,281	Degraded	Degraded	Intermediate	Intermediate	6 to 10
		Shorebirds	1,214	Degraded	Degraded	Good	Good	6 to 10
		Water Quality	1,298	Degraded	Degraded	Intermediate	Intermediate	6 to 10
		Wetland Vegetation	NA	Intermediate	Intermediate	Intermediate	Intermediate	NA
Caddo Lake	2010	Fisheries	809	Intermediate	Good	Good	Good	6 to 10
		Floodplain Connectivity	809	Degraded	Degraded	Intermediate	Intermediate	More than 20
		Water Quality	809	Intermediate	Good	Good	Good	6 to 10

		Flood Protection	809	Degraded	Degraded	Intermediate	Intermediate	More than 20
Green River	2002	Mussels	4,989	Degraded	Intermediate	Good	Good	11 to 20
		Fisheries	4,989	Degraded	Intermediate	Good	Good	6 to 10
		Recreation	1,331	Intermediate	Good	Good	Good	3 to 5
		Habitat Enhancement	1,331	Degraded	Intermediate	Good	Good	11 to 20

The following SRP sites were not included in the aggregation analysis due to insufficient data:

Tule River	Arkansas River	Tenn-Tom Waterway
Pecos River	Fourche La Fave River	Tombigbee River
Ballard Locks	White/Black/Little Red Rivers	Alabama River
Yakima River Delta (McNary)	Minnesota River	Coosawattee River
Walla Walla River (Mill Creek)	Farm Creek	Chattahoochee River
Kootenai River	Bayou Courtableau	Apalachicola River
Cherry Creek	Wabash River	Savannah River
James River	Ohio River	Neuse River
Kansas River	Rough River	Potomac River
Osage River	Nolin River	Lehigh River
Brazos River	Cumberland River	Connecticut River
Trinity River	Sugar Creek	Kanawha River
Neches River	Twelve Pole Creek	

Table 5-2 NPV and BCR for SRP Portfolio, 2020–2040

		2020	2025	2030	2035	2040
Scenario 1	NPV	$37,911,632	$89,997,500	$162,707,764	$222,728,936	$265,139,820
	BCR	7.56	5.31	8.79	11.66	13.69
Scenario 2	NPV	$37,911,632	$89,588,974	$155,931,740	$207,024,846	$243,040,699
	BCR	7.56	5.29	8.46	10.91	12.63

Using the Scenario 1 approach, the four case study sites combined with the additional program sites yield an estimated NPV of approximately $265 million and a BCR of 13.69 through 2040. Under the Scenario 2 approach, the estimated NPV is approximately $243 million, with a BCR of 12.63. In both scenarios, the program generates substantial economic returns relative to costs. However, because several strong assumptions are required to estimate aggregated benefits, these results should be interpreted as order-of-magnitude estimates of program value rather than precise valuations.

6. Conclusion

SRP delivers strong returns on investment through quantifiable ecosystem service benefits. These benefits will continue to accrue over time, provided that USACE Districts continue to implement SRP-recommended actions.

Across all four SRP project sites, the results demonstrate that the program is highly cost-effective, delivering positive returns on investment within only a few years. By 2040, Mel Price achieves an NPV of $2.70 million and a BCR of 12.43, with benefits exceeding costs within just three years. The Des Moines River, while its benefits lag costs until approximately 2028, ultimately delivers the largest absolute gains, with an NPV of $17.7 million and a BCR of 8.98. Caddo Lake, though smaller in scale, generates efficient and early returns, producing an NPV of $2.86 million and a BCR of 7.89, with benefits surpassing costs from 2015 onward. The Green River has already realized more than $18 million in benefits since 2010 and is projected to exceed $34 million by 2040. At the portfolio level, including both the case study sites and additional program sites, the SRP as a whole provides positive returns, with an NPV ranging from $243 million to $265 million and a BCR ranging from 12.63 to 13.69 through 2040. Taken together, these outcomes demonstrate that SRP investments consistently yield high returns relative to costs, reflecting strong short- and long-term cost-effectiveness across diverse ecological contexts.

These results are based on two primary sources of information: cost data from 2010 to 2024 provided by USACE staff for each site, and estimated ecosystem service values associated with intended benefits from environmental actions at each site. Benefit valuation was conducted using a benefit transfer approach, which enables estimation in the absence of site-specific primary data collection. Although this method follows a well-established meta-analytic transfer regression framework, the results should not be interpreted as precise measurements due to inherent limitations in capturing all site-specific variables. Nevertheless, the regression model draws on a dataset of 55 studies, which helps minimize extrapolation error and improve the overall robustness of the estimates.

It is important to note that cost estimates include only expenditures incurred directly by SRP. Implementation of environmental actions at each site was also supported by several partners, including state, regional, federal, and nonprofit organizations. These partners' financial and in-kind contributions were essential to project success; however, while they are acknowledged here, they were not monetized in this analysis. Because detailed cost-sharing data were unavailable, we cannot attribute precise portions of total costs exclusively to SRP. Incorporating these additional contributions would increase total costs and, in turn, reduce the estimated NPVs and BCRs. Nonetheless, tracking expenditures by USACE—the owner and manager of all infrastructure subject to SRP—is critical for understanding the value of SRP investments from a federal perspective.

Net benefits were estimated by comparing two scenarios: a baseline (no-action) scenario and an SRP implementation scenario. Changes in ecosystem service values were informed by site representatives' input on expected changes in ecosystem conditions associated with intended benefits. This approach assumes that observed changes are primarily attributable to SRP actions; however, we acknowledge that external factors, such as weather variability, may also influence outcomes and could lead to under- or overestimation of impacts in the short term. Because the analysis evaluates benefits over multiple decades, short-term weather-related variability is expected to average out, allowing the estimates to more closely reflect the long-term average effects of SRP actions.

All estimates relied on the expert judgment of site representatives with in-depth knowledge of dam operations, SRP implementation, site monitoring, and ecosystem conditions. While their input reflects well-informed and credible expertise, a comprehensive ecological assessment supported by empirical data would be required for more rigorous validation. In addition, the identification of intended benefits and corresponding ecosystem services was driven primarily by these site representatives; a broader expert elicitation process would improve the completeness and validation of ecosystem service selection. Finally, the analysis was constrained by the ecosystem service categories available within the TEEB classification, which limited our ability to quantify services beyond those captured under this framework.

In sum, while the estimates involve uncertainty, the overall direction of the results is robust, leading us to conclude that SRP delivers strong returns on investment through quantifiable ecosystem service benefits. These benefits are expected to continue accruing over time, provided that USACE districts continue to implement SRP-recommended actions and maintain associated environmental improvements.

7. Acknowledgments

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Appendix A

Tables

Table A-1 TEBB Ecosystem Services Classification

Service	Ecosystem Service	ES Code
Provisioning	Food	1
Provisioning	Water	2
Provisioning	Raw materials	3
Provisioning	Genetic resources	4
Provisioning	Medicinal resources	5
Provisioning	Ornamental resources	6
Regulating	Air quality regulation	7
Regulating	Climate regulation	8
Regulating	Moderation of extreme events	9
Regulating	Regulation of water flows	10
Regulating	Waste treatment	11
Regulating	Erosion prevention	12
Regulating	Maintenance of soil fertility	13
Regulating	Pollination	14
Regulating	Biological control	15
Habitat	Maintenance of life cycles	16
Habitat	Maintenance of genetic diversity	17
Cultural	Aesthetic information	18
Cultural	Opportunities for recreation and tourism	19
Cultural	Inspiration for culture, art and design	20
Cultural	Spiritual experience	21
Cultural	Information for cognitive development	22
Cultural	Existence, bequest values	23
Habitat	Maintenance of life cycles	16
Habitat	Maintenance of genetic diversity	17
Cultural	Aesthetic information	18
Cultural	Opportunities for recreation and tourism	19
Cultural	Inspiration for culture, art and design	20
Cultural	Spiritual experience	21
Cultural	Information for cognitive development	22
Cultural	Existence, bequest values	23

Source: https://www.esvd.info/classifications

Table A-2 Summary Statistics of Variables Used in the Meta-Regression (n = 55 Studies)

Variable	Type	Description	Mean	SD
Dependent Variable				
log(ES value)	N	Natural log of ecosystem service value (2025 USD/ha/year)	6.26	2.03
Site Characteristics				
log(Site area)	N	Natural log of site area (ha)	10.01	3.71
Ecosystem condition: Intermediate	D	=1 if intermediate condition (ref. = degraded)	0.62	0.49
Ecosystem condition: Well-functioning	D	=1 if well-functioning (ref. = degraded)	0.28	0.45
Mean MSA	N	Mean species abundance (biodiversity proxy)	0.35	0.17
Biome Type				
Intensive land use	D	=1 if biome = intensive land use	0.54	0.5
Rangelands / grasslands	D	=1 if biome = rangelands & natural grasslands	0.17	0.37
Rivers and lakes	D	=1 if biome = rivers and lakes	0.04	0.19
Temperate forest / woodland	D	=1 if biome = temperate forest & woodland	0.13	0.34
Ecosystem Service Category				
Food	D	=1 if ES code = 1	0.67	0.47
Water	D	=1 if ES code = 2	0.19	0.39
Extreme event moderation	D	=1 if ES code = 9	0.09	0.29
Water flow regulation	D	=1 if ES code = 10	0.04	0.2
Waste treatment	D	=1 if ES code = 11	0.02	0.13
Erosion prevention	D	=1 if ES code = 12	0	0.05
Soil fertility maintenance	D	=1 if ES code = 13	0.1	0.3
Biological control	D	=1 if ES code = 15	0.02	0.14
Life-cycle maintenance	D	=1 if ES code = 16	0	0.05
Genetic diversity	D	=1 if ES code = 17	0.02	0.13
Aesthetic information	D	=1 if ES code = 18	0.01	0.11
Recreation & tourism	D	=1 if ES code = 19	0.07	0.25
Existence / bequest	D	=1 if ES code = 23	0.03	0.18
Valuation Method				
Contingent valuation (CV)	D	=1 if method = contingent valuation	0.12	0.33
Market price (MP)	D	=1 if method = market price	0.51	0.5
Production function (PF)	D	=1 if method = production function	0.05	0.22
Replacement cost (RC)	D	=1 if method = replacement cost	0.16	0.37

Notes: N = continuous variable; D = dummy variable. All monetary values are expressed in 2025 USD. Reference categories omitted from the table include degraded ecosystem condition and valuation methods not listed.

Table A-3 Meta-Regression Model Results

Variable	Coef.	SE
Site Characteristics		
Intercept	3.770***	0.982
log(Site area)	0.03	0.032
Ecosystem condition: Intermediate	1.414***	0.436
Ecosystem condition: Well-functioning / extensively managed	1.593***	0.46
Mean MSA	0	0.567
Biome		
Intensive land use	0	0.403
Rangelands & natural grasslands	−0.365***	1.028
Rivers and lakes	0.216	0.455
Temperate forest & woodland	−1.114***	0.705
Ecosystem Service Category		
Food	−0.088***	0.277
Water	−1.200⁺	0.307
Extreme event moderation	1.087	0.671
Water flow regulation	0.159	0.491
Waste treatment	0.626	0.758
Erosion prevention	−0.626***	1.008
Soil fertility maintenance	−1.105***	0.504
Biological control	0.301⁺	0.855
Life-cycle maintenance	−2.175***	1.324
Genetic diversity	−1.376	0.649
Aesthetic information	0.000*	0.862
Recreation & tourism	0.878	0.806
Existence / bequest values	−1.639	0.566
Valuation Method		
Contingent valuation	0.439	0.813
Market price	1.265**	0.943
Production function	1.056⁺	1.256
Replacement cost	0.082	1.038

Model fit	
Observations	55
R^2	0.520
Adjusted R^2	0.492

Notes:
⁺ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Reference categories omitted for ecosystem condition, biome, ecosystem service category, and valuation method

Table A-4. NPV and BCR for Each Site, by year, 2010–2040, Using a 7% Real Discount Rate

	NPV			BCR		
	Caddo Lake	Des Moines River	Mel Price	Caddo Lake	Des Moines River	Mel Price
2010	-$43,156	$0	$0	0.00	0.00	0.00
2011	-$77,502	$0	$0	0.10	0.00	0.00
2012	-$107,911	$0	$0	0.20	0.00	0.00
2013	-$95,636	$0	$0	0.35	0.00	0.00
2014	-$101,616	$0	$0	0.46	0.00	0.00
2015	-$96,509	-$29,116	$0	0.57	0.00	0.00
2016	-$66,146	-$29,116	$0	0.73	0.00	0.00
2017	-$9,067	-$99,502	$0	0.96	0.00	0.00
2018	$54,611	-$118,240	$0	1.22	0.00	0.00
2019	$106,569	-$175,908	$0	1.41	0.00	0.00
2020	$31,081	-$646,183	$0	1.07	0.00	0.00
2021	$112,221	-$891,606	-$85,667	1.27	0.00	0.00
2022	$194,180	-$988,076	-$67,600	1.47	0.00	0.58
2023	$279,457	-$1,720,067	$31,964	1.67	0.00	1.13
2024	$368,662	-$2,220,209	$289,529	1.89	0.00	2.22
2025	$476,105	-$1,851,556	$530,201	2.15	0.17	3.24
2026	$598,794	-$1,165,861	$755,082	2.44	0.47	4.19
2027	$734,070	-$209,317	$965,204	2.77	0.91	5.08
2028	$879,568	$976,798	$1,161,531	3.12	1.44	5.90
2029	$1,033,195	$2,355,657	$1,344,964	3.49	2.06	6.68
2030	$1,193,100	$3,894,463	$1,516,348	3.87	2.75	7.40
2031	$1,357,650	$5,564,068	$1,676,469	4.27	3.51	8.08
2032	$1,525,413	$7,338,620	$1,826,066	4.67	4.31	8.71
2033	$1,695,132	$8,988,953	$1,965,387	5.08	5.05	9.30
2034	$1,865,711	$10,523,762	$2,095,138	5.49	5.74	9.85
2035	$2,036,199	$11,951,135	$2,215,976	5.90	6.38	10.36
2036	$2,205,771	$13,278,592	$2,328,513	6.31	6.98	10.83
2037	$2,373,721	$14,513,127	$2,433,320	6.72	7.54	11.27
2038	$2,539,446	$15,661,244	$2,530,926	7.12	8.05	11.69
2039	$2,702,433	$16,728,993	$2,621,828	7.51	8.53	12.07
2040	$2,862,254	$17,722,000	$2,706,484	7.89	8.98	12.43