US Army Corps of Engineers
St. Paul District

Scoping Document

Appendix C: Scoping Comments

Lower St. Anthony Falls Lock and Dam and Lock and Dam 1

Section 216 Disposition Study

May 2023

Corps of Engineers, St. Paul District
332 Minnesota Street, Suite E1500, St. Paul, MN 55101

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C.1 Agency Comments

C.1.1 Minnesota Department of Natural Resources

Office of the Regional Director
Region 3 Headquarters
1200 Warner Road
Saint Paul, MN 55106

Transmitted by Email

December 16, 2022

David Potter
U.S. Army Corps of Engineers St. Paul District
ATTN: Regional Planning and Environment Division North
332 Minnesota St., Suite E1500
St. Paul, MN 55101

Dear David Potter,

Thank you for the opportunity to provide scoping comments for the US Army Corps of Engineers' (USACE) Lower St. Anthony Falls (LSAF) and Lock and Dam 1 (LD 1) Disposition Study (DS). The Minnesota Department of Natural Resources (DNR) has a vested interest in the outcome of the DS and selected action given our role in managing Minnesota's public waters. The Mississippi River is a nationally significant watercourse, and this eight-mile stretch is a tremendous environmental, recreational, economic, and cultural resource for our state. The DS presents a unique opportunity to consider the future of this resource with intention and thoughtfulness. DNR appreciates the opportunity to share our comments as you enter into this work, and we're ready to discuss these comments as the scoping and study process moves forward.

Alternative Analysis

Emphasis and Scope

The DNR would like to see a robust study that thoroughly considers all potential options, including dam removal. Given the significance of the Upper Mississippi River, it is important that the DS and Tentatively Selected Plan (TSP) weigh environmental and cultural considerations more heavily than currently proposed, and consider them as well as economic cost in a balanced manner.

The USACE's October 18, 2022 Agency Meeting presentation indicated that economic considerations would be most heavily weighted in evaluating disposition alternatives, and that any plan that was more expensive than the cost of continued maintenance would not be considered based on the USACE implementation document that was created to interpret the Water Resources Development Act (WRDA) of 2018. USACE stated at the meeting that a separate directive from U.S. Congress would be required to fully evaluate environmentally beneficial actions, including river restoration. Through WRDA 2018, Section 1168(a), U.S. Congress specifically mandates that the disposition study for LSAF and LD1, "consider modifications that would **improve the overall quality of the environment in the**

public interest, including removal of the project or separable element of a project." Therefore, ecosystem services, benefits to rare species, and recreation opportunities that improve the overall quality of the environment in the public interest must be considered when selecting the preferred alternative since U.S. Congress has already provided this direction.

One Disposition Study

The DNR strongly supports considering LSAF and LD 1 in one disposition study because of the interrelated effects these locks and dams have in shaping the habitat, recreation, and nature of this stretch of the Mississippi River. At the same time, we understand that, within the single study, USACE must examine the opportunities and constraints for each lock and dam individually as well as collectively.

Future Economic Considerations

If LSAF and Lock and Dam 1 are no longer supporting commercial navigation, it is unknown if future funding levels would be sufficient to maintain the locks and dams and prevent the structures from falling into disrepair. The DNR has serious concerns about the future of the locks and dams if these structures are no longer prioritized for federal funding. When evaluating alternatives, the USACE should identify the expenditures that would be necessary to maintain the locks and dams in a safe and functional condition. This should be done for the full life of the structure, including what costs will occur once these structures reach the end of their life and require significant recapitalization, removal, or replacement.

Similarly, it is also important that the economic benefits as well as costs of dam removal and restoration of the river and its floodplain from St. Anthony Falls to the Ford Dam be part of the dam removal and restoration alternatives. This would include the economic impacts of resulting additional riverfront land, and changes in the types and level of river-based recreation. These factors should be considered within the analysis to the greatest degree possible to gain the most accurate understanding of the true costs associated with the removal alternative.

It is important that the DS includes a level of detail and analysis sufficient to accurately compare the removal option costs and benefits to other alternatives.

Environmental Considerations

In 1917, when the U.S. Congress directed USACE to construct these locks and dams along this significant stretch of our nation's largest river, the footprint, uses, and habitat of the Mississippi River was profoundly transformed. This was a federal decision, and likewise there is a federal obligation to ensure that the future operation and maintenance, or removal, of these structures is responsibly and adequately addressed.

In evaluating disposition alternatives for LSAF and LD 1, the DS must consider how the alternatives will impact or diminish the ecological integrity of the Mississippi River system. The locks and dams in question were built atop one of the only rapids on the entire Mississippi River. High gradient rapids and riffles, as well as cobble and boulder substrates, are biological hotspots that provide crucial spawning area for numerous rare species, including threatened and endangered species (e.g., blue sucker, paddlefish, and lake sturgeon). This habitat would have historically been important for many native species, some of which are now state or federally listed. Before the locks and dams were constructed, the migration of fish from long distances was beneficial for mussels to continually repopulate upstream reaches. The DS should consider how the removal alternative and restoration of the physical habitat throughout the area would allow fish that serve as hosts for many species of state and federally threatened and endangered mussels to bring them up river and into the type of habitat that they need to survive and begin reproducing. This connectivity could increase the likelihood of recovering and delisting these species. The restored unique riverine habitat could once again support the federally endangered: Winged Mapleleaf, Spectaclecase, Snuffbox, Higgins' Eye and Sheepnose mussels that once lived in this part of the Mississippi River.

The DS should fully acknowledge the broad impacts the locks and dams have had on the entire river system with effects that go well beyond impacts to threatened and endangered species in the direct vicinity and footprint of the structures themselves. The DS should also consider the ongoing impacts these dams have in their present condition, and the potential effects if the dams were removed.

Cultural Considerations

The environmental justice sections of the DS should consider equitable access for the public to access, utilize, and understand the river. Alternatives should take into account potential impacts to culture and history of the Dakota people.

Unknown Potential Future Owners and Use

The DNR believes the TSP should include details about potential owners and how they might use the facility, or what the next step would be if no interested party comes forward. The DS should discuss responsibilities that will be passed to a new owner, including invasive carp management, maintenance responsibilities, and flood risk management. USACE has explained during DS Scoping meetings that the General Services Administration (GSA) Disposal Process will be used for the conveyance of federal properties. The GSA process does not consider or establish criteria by which the capacity and suitability of a potential owner would be evaluated in relation to these risks and responsibilities, nor does it clarify what type of financial assurance would be required to protect the public interest and safety should a new owner fail to perform its obligations. If a private company walks away from such large costs and responsibilities, the state of Minnesota could ultimately become responsible for these structures at the end of their life cycles. The DS should establish criteria by which to evaluate the capacity and suitability of a potential new owner in relation to their responsibilities and above risks, and clarify what type of financial assurance would be required to protect the public interest and safety should a new owner fail to perform its obligations.

DNR Regulatory Responsibilities

The DS should inform potential owners that activities affecting the land and infrastructure covered by the DS are subject to Minnesota law and may need state agency permits and approvals. The DS does not substitute for environmental review that may be required for any project a new owner proposes in the future. We invite interested parties to consult with DNR regarding state requirements under our jurisdiction that are relevant to their contemplated use. Similarly, we strongly encourage any entity(ies) that ultimately assumes ownership to include DNR early in their planning efforts. The remaining points in this section provide interested parties with a non-exhaustive list of potential regulatory issues under DNR's jurisdiction.

Public Waters

A DNR Public Waters Work Permit and/or DNR Water Appropriation Permit could be required, depending on the nature of the activity/project. A DNR permit can be applied for using the MNDNR Permitting and Reporting System.

State-listed Species

There are numerous state-listed threatened and endangered species throughout this section of the Mississippi River. Future owners would need to coordinate with DNR regarding potential project impacts to state-listed species. This process can be initiated through https://mce.dnr.state.mn.us/.

State Trails

The Mississippi River is a state-designated water trail administered by the DNR. The DNR seeks to maintain recreational corridor connectivity with the state water trail and portage routes. Following any disposition of LSAF or LD1, DNR will want to ensure that a safe, sustainable, and easily used portage stays in place. DNR may also want to explore other public water access options for motorized watercraft, if compatible with the disposition of LSAF and LD 1.

Conclusion

This stretch of the Mississippi River retains tremendous natural, cultural, and recreational resources in its current state and also presents significant potential for natural resource restoration and enhancement, and acknowledgment of the cultural significance of the area. There are diverse and strongly held interests in the future of the Mississippi River throughout this region, and it is essential that this study employs a robust and transparent approach to identifying and assessing a full range of alternatives. In addition to economic considerations, the DS should address the broader context, range of potential options, and full suite of ecological, recreational, social, and institutional factors in planning the future of this interconnected federal infrastructure that has profoundly shaped the Mississippi River through Minneapolis and St. Paul.

Thank you again for the opportunity to provide input during the scoping of the LSAF and LD 1 Disposition Study. The DNR looks forward to further discussion on the future of this critically important section of the Mississippi River.

Sincerely,

Grant L. Wilson

Central Region Director
Minnesota Department of Natural Resources

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Equal Opportunity Employer

C.1.2 National Park Service

United States Department of the Interior

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IN REPLY REFER TO:
1 A 2 (MISS)

14 December 2022

Colonel Eric Swenson
District Engineer
St. Paul District, U.S. Army Corps of Engineers
ATTN: Regional Planning and Environment Division North
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St. Paul, MN 55101

Dear Colonel Swenson:

Please find attached the Mississippi National River and Recreation Area's comments on the "Scoping for the Lower St. Anthony Falls Lock and Dam and Lock and Dam 1 Disposition Study." In this cover letter, we address the special context of these locks and dams and of the Mississippi River in the Twin Cities.

While the National Park Service manages other units on the Mississippi River, the Mississippi National River and Recreation Area (NRRA) is the only one whose mission and focus is the Mississippi River, one of the great rivers of the world. We are the Mississippi River's National Park. Whatever the outcomes of the USACE Disposition Study, they will impact this National Park Service unit, so we have a special interest and stake in the Disposition Study.

Congress established the NRRA in 1988 with the direction "To protect, preserve and enhance the significant values of the waters and land of the Mississippi River Corridor within the Saint Paul-Minneapolis Metropolitan Area." Congress emphasized that "There is a national interest in the preservation, protection and enhancement of these resources for the benefit of the people of the United States." The National Park Service, therefore, has a responsibility to the American people to ensure any future actions protect, preserve and enhance the significant values here. This is a national conversation, not just local, which is why organizations like the National Parks Conservation Association and American Rivers are weighing in.

It is important that this study consider the broader scope of disposition and not just USACE's structures and real estate at the locks and dams. These locks and dams and the nine-foot channel are a significant nexus for the Mississippi River from the Upper Harbor Terminal to the confluence of the Minnesota River. The fish, wildlife, and people of the entire region will be affected by the outcome of this study.

Lower St. Anthony Falls Lock and Dam and Lock and Dam 1 sit in the reach locally referred to as the "Gorge." The Gorge stretches 8.5 miles, from St. Anthony Falls to the mouth of the Minnesota River. Nowhere on the Mississippi does the river drop so quickly over such a short distance and through such a narrow canyon. From above St. Anthony Falls to the Minnesota River, the Mississippi plummets 110 feet. The bluffs are 80 to 100 feet high and only one-quarter to one-third of a mile apart. Before the locks and dams, a turbulent rapids rushed through the gorge at high water. At low flows, the Gorge became a shallow stream filled with sand, gravel, and rock bars. Parkways now define both sides and are part of the Grand Rounds National Scenic Byway.

This area of the river is a premier regional and national destination for recreation and is the heart of recreation for the Twin Cities attracting millions of people every year. The Mississippi River's only National Water Trail, the Mississippi National River and Recreation Area National Water Trail is in this section of river. The National Water Trail is one of only a few nationally designated water trails that promote recreation and use of rivers with nationally significant resources. Currently Lower St. Anthony Falls Lock and Dam and Lock and Dam 1 serve as significant hazards and impediments for users to recreate along the National Water Trail.

As the history behind the NRRA's creation demonstrates, the State of Minnesota is also committed to protecting, preserving, and enhancing the resources of the Mississippi River through the Twin Cities. In 1973, the State passed the Critical Areas Act to protect areas with exceptional historic, cultural, or aesthetic values or natural systems. Three years later, Governor Wendell Anderson established a 72-mile stretch of the Mississippi River, including a 4-mile reach of the Minnesota River, and the adjoining lands in the Twin Cities metropolitan region as the state's first Critical Area. In 1979, Governor Albert Quie extended the Mississippi River Corridor Critical Area designation (E.O. 17-19), and the Metropolitan Council (Resolution 79-48) made the designation permanent that same year.

When Congress established the NRRA in 1988, it used the same boundary as the Critical Area and did not mandate new rules and regulations. Instead, the State agreed to ensure protection of the significant resources through State laws and regulations. In a key step honoring that agreement, the Minnesota Legislature designated the NRRA a State Critical Area in 1991. Further binding the NRRA to the Mississippi River Corridor Critical Area, the Mississippi River Coordinating Commission (1994), Minnesota Governor Arne Carlson (1994), and Secretary of the Interior Bruce Babbitt (1995) signed the NRRA's Comprehensive Management Plan.

One final, compelling point for the USACE to consider carefully its conclusions and recommendations for the Disposition Study: the study's outcome will likely shape the river in the Twin Cities for generations to come. From their founding in the mid-nineteenth century, Minneapolis and St. Paul began shaping the Mississippi River for navigation and hydropower through the Corps of Engineers and private entities. For the first time since then, there is opportunity to consider a new relationship with the river.

As the above background shows, the Mississippi River through the Twin Cities is of exceptional importance to the nation and to State and local communities. Consequently, we have high expectations for a deep and broad analysis to help the American people understand all that disposal, modification, or removal mean. Individual interests will advocate for preserving or protecting a particular stake or aspect of the Mississippi River tied to one or more of the locks and dams. As outlined in the attached comments, the NRRA must consider all seven resources identified by Congress in our authorizing legislation and assess the overall benefits or losses of any particular action or recommendation by the USACE.

For the NRRA to fully and fairly do this, we need the USACE to thoroughly respond to the questions we ask and the concerns we raise in our attached comments, as well as to those asked and raised by other interests. We will be available at any time during your analysis to help in whatever way we can.

If you have any questions, please contact me at [redacted].

Sincerely,

Matthew T. Blythe

Matthew T. Blythe
Superintendent

Attachment: Lower St. Anthony Falls Lock and Dam, Lock and Dam 1 Disposition Study Scoping Comments

Statutory Requirements

The Act establishing the Mississippi National River and Recreation Area (NRRA) on November 18, 1988, (Public Law 100-696) explains why Congress created the park and defines what the National Park Service (NPS) needs the Disposition Study to address.

TITLE VII – MISSISSIPPI NATIONAL RIVER AND RECREATION AREA, Subtitle A – Mississippi
National River and Recreation Area, FINDINGS AND PURPOSES

- Sec. 701 (a) FINDINGS. – Congress finds that:
    - The Mississippi River Corridor within the Saint Paul-Minneapolis Metropolitan Area represents a nationally significant historical, recreational, scenic, cultural, natural, economic, and scientific resource.
    - There is a national interest in the preservation, protection and enhancement of these resources for the benefit of the people of the United States.

- Sec. 701 (b) PURPOSES. – The purpose of this subtitle are:
    - To protect, preserve and enhance the significant values of the waters and land of the Mississippi River Corridor within the Saint Paul-Minneapolis Metropolitan Area.

To adequately evaluate the potential impacts of the No Action and Deauthorization/Disposal alternatives at Lower St. Anthony Falls Lock and Dam and Lock and Dam 1, the USACE needs to identify and assess the potential impacts to the seven resource types identified in Sec. 701(a).

Because these resources are of national significance, the NRRA's authorizing legislation also states:

Sec. 704 (b) FEDERAL AGENCY ACTIVITIES

(1) IN GENERAL.
— Before any department, agency, or instrumentality of the United States issues or approves any license or permit for any facility or undertaking with in the Area and before any such department, agency, or instrumentality commences any undertaking or provides any Federal assistance to the State or any local governmental jurisdiction for any undertaking within the Area, the department, agency, or instrumentality shall notify the Secretary. The Secretary shall review the proposed facility or undertaking to assess its compatibility with the plan approved under section 703[1]. The Secretary shall make a determination with respect to the compatibility or incompatibility of a proposed faculty or undertaking within 60 days of receiving notice under this subsection. If the Secretary determines that the proposed facility or undertaking is incompatible with the plan, he shall immediately notify such Federal department, agency, or instrumentality and request such department, agency, or instrumentality to take the actions necessary to conform the proposed facility or undertaking to

[1] This "plan" is the 1994 Mississippi National River and Recreation Area Comprehensive Management Plan (CMP)

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the plan. The Federal department, agency, or instrumentality shall,
within 60 days after receiving the Secretary's request, notify the
Secretary of the specific decisions made in response to the request.
To the extent that such department, agency, or instrumentality does
not then conform such facility or undertaking to the request of the
Secretary, the Secretary is directed to notify the Congress in
writing of the incompatibility of such facility or undertaking with
the plan approved under section 703.
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We would also like to call attention to Sec. 1168 of the America's Water Infrastructure Act of 2020 as it specifically highlights considering modifications that improve the overall quality of the environment in the public interest and removal of the project. In some of the public engagement meetings we have heard the USACE express economic considerations are the primary study subject, while we believe that Congress' intent is to prioritize environmental quality.

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SEC. 1168. -- DISPOSITION OF PROJECTS.

    (a) -- In General.--In carrying out a disposition
study for a project of the Corps of Engineers, or a separable element of
such a project, including a disposition study under section 216 of the
Flood Control Act of 1970 (33 U.S.C. 549a), the Secretary shall consider
modifications that would improve the overall quality of the environment in
the public interest, including removal of the project or separable element
of a project.
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Scoping Comments Based on the Seven Resource Types

The descriptions of the seven resource types[2] below are not comprehensive, but an outline of what the USACE should study. We recognize that positive impacts to one type of resource could negatively affect another. The Mississippi National River and Recreation Area Comprehensive Management Plan (CMP), developed in accordance with Sec. 703 (i), provides "a general framework to coordinate natural, cultural, and economic resource protection, visitor use, and development activities" (CMP, General Concept, p. 11). It details policies and actions for seven resource types that contribute to the significance of the area, but it distinctly "recognizes the national significance of the Mississippi River as a natural riverine ecosystem." In doing so, the CMP states that "fish and wildlife resources, including bottomland forests, bluffland, and riverine habitats will receive greater protection" (CMP p. 12). We will look at all the impacts, however, and weigh the overall effects. (For a copy of the CMP contact the park.)

From Lock and Dam 1 to the confluence of the St. Croix River, the Mississippi River is Federally classified as having Outstanding Resource Values (ORVs) in Geologic, Historic, Recreational, Scenic and Wildlife categories. This is the only section of the Mississippi River federally recognized for having ORVs. ORVs can only be designated for river sections that are generally free of impoundments and if the lock and dams were removed these ORVs likely continue to St. Anthony Falls.

<u>1. Economic Resources</u>. The NPS focuses on economic uses of the corridor consistent with the values for which the area was established. Commercial barge shipping, tour boats, marinas, recreation, tourism and hydroelectric power generation fit this focus. The park's authorizing legislation stresses that the park protect, preserve and enhance those uses and resources of national significance, although we also consider the importance of local and regional significance.

[2] Note that historical and cultural resources are combined in the same section

- Any change in the dam should consider the impacts to economic use of the river. To determine impacts the USACE should first set a baseline by studying the current economic impact of activities likely to be effected by a change in operations – including hydroelectric generation at the dams, fishing via motorized boats, commercial tour boat operators, and rowing clubs and teams.

2. Historical and Cultural Resources. The cultural resources of the area consist of evidence of past activities on or near the river. These include burial mounds, campsites, village sites, and ethnographic resources that illustrate the nature of the occupation by Native Americans. The fur trading period, early settlement, and later urbanization, as well as agricultural and industrial activity on or near the river, are included in historic districts, national historic landmarks, national register properties, and locally designated historic sites. Both lock and dam sites have been determined eligible for the National Register of Historic Places.

- The removal of either dam will have a tremendous impact not only the dam structures themselves but the corresponding impoundments. The entire stretch of the river from St. Anthony Falls to below Lock and Dam 1 should be considered the primary Area of Effect for study of the dam structures. As the deauthorization of the nine-foot navigation channel is also within the scope of the study, the entire stretch of the river from the confluence with the Minnesota River to the Upper River Harbor Terminal Site should be included in the Area of Effect.

3. Natural Resources. The natural resources of the NRRA are considered to be the assets or values related to the natural world, such as plants, animals, birds, water, air, soils, geologic features, fossils and scenic vistas. Natural resources are those elements of the environment not created by humans, although they have been affected by human action. The most important natural resource in the corridor is the Mississippi River itself. It is a globally significant riverine ecosystem that must be protected and restored because it serves, in part, as a migratory corridor for wildlife, because it is essential to sustaining the biological diversity of the continent and the natural functions of the numerous aquatic and terrestrial communities of which it is composed, and because it supports the quality of life for the citizens who live and work and play on and near it.

- The NPS has conducted biological surveys and studies in comparable Mississippi River habitats to those in Pool 1 and the Intermediary Pool and found significant aquatic and terrestrial biodiversity. The current condition of the following fish and wildlife in the study area is unknown and should be investigated along with any possible impacts to a change in lock and dam:
  - Beavers, otters, fishers, and other mammals have a direct relationship to the river and have been found in the area.
  - Frogs and other amphibians: the cricket frog which is state listed as endangered has been found in the area.
  - Migratory birds: a change in water levels or fish could have an impact on the nation's largest migratory flyway
  - Mussels and fish populations: there are a number of listed mussel species in the study area.
- If the nine-foot navigation channel is deauthorized and dredging ceases what will the makeup of the river bottom be long term? The study should explore if there will be an impact to fish and wildlife in river and riparian zones through a build-up of sediment.
- Dam removal would improve ability for fish to traverse the river to spawn, although it would also make it easier for Asian Carp to make their way upriver. Removal would likely increase fish diversity in this stretch of river over time, benefitting the resource as a whole. The impacts on native and nonnative fish migration should be studied.
- Removal would allow for the river to revert to a more natural floodplain and rapids in that area, improving habitat for a variety of species including mussels. This could lead to increased bird and

mammal diversity in the area as well. The positive environmental impacts from this should be studied.

- The sediment accumulation issue behind the dams needs to be addressed and sediment tested for contaminants and removed well before any movement is made on dam removal.

<u>4. Recreational Resources</u>. The park was specifically designated a Recreation Area. The corridor offers a broad range of recreational and educational experiences closely tied to the character of the resource and complementing other recreational opportunities in the metropolitan area. The variety of passive and active resource-related recreational activities in the study area include fishing, hunting, boating, canoeing, rowing, cross-country skiing, snowshoeing, hiking, bicycling, jogging, picnicking, taking photographs, dog park use, birding, ice climbing, and participating in a variety of interpretive and educational programs. The study area is also home to the Mississippi National River and Recreation Area National Scenic Water Trail, which is the only National Water Trail on the Mississippi River and one of the first in the nation.

- If the locks cease to operate and the dams remain, access to the river would be significantly reduced. A study should include evaluation for increased water access on Pool 1, where there are currently no public motorized boat accesses and only three non-motorized boat accesses. The study must also evaluate the addition of a public water access to the intermediary pool as there are none currently.
- If the locks cease to operate and the dams remain or if the water becomes unnavigable for most paddle craft after dam removal, the study will need to identify an accessible portage for National Water Trail users. Currently the designated portage is poorly identified and difficult to use.
- There is currently concern over the loss of sport rowing (crew) recreation if the dams were to be removed. The study should include an assessment of current sport rowing recreation levels on Pool 1 and identify if the region has comparable water bodies that could accommodate that level of use if displaced.
- If the locks and dams are removed it will create opportunities for new recreation possibly including white water rafting, kayaking, and fly fishing. This study should include projected use in these recreation types along with the potential decrease in recreational use from the loss of large commercial pleasure vessels and sport rowing. To accomplish such a study the USACE should study the base line of use at public water accesses, recreational lockages, and sport rowing clubs.
    - In 1999 the Minnesota Department of Natural Resources (DNR) completed a report for the establishment of a white water park in the Intermediary Pool and found it feasible. This study provides an opportunity to revisit the 1999 DNR study.
- Lock and Dam 1 offers one of the few accessible access points to the river in the area of study. If operation of the lock and dam changes to one where there is no public access, the impact on accessible opportunities to experience the river up close in this area should be studied.

<u>5. Scientific Resources</u>. Scientific resources have not been defined specifically, but they include resource related issues and research that can provide a better understanding of the Mississippi River's past and potential future. The park's paleontological remains are an example of resources related to research opportunities and education. These remains lie within the bedrock layers of the river's bluffs and date to the Ordovician Period (444 to 488 million years ago). Research on water quality, plants, wildlife which includes birds and insects, the river's fish and mussel populations, changing climate conditions on river flow, and what the river was like before it was dammed for hydropower and navigation all fit under scientific research that would benefit the river and its resources. (See CMP pg. 29 Resources Management and "scientific research.)

<u>6. Scenic Resources</u>. The corridor includes many outstanding vistas, areas of scenic beauty, and tranquil places in the midst of a large urban area. Scenic views can vary from an entirely wild and natural looking setting to the cityscapes of Minneapolis, St. Paul and other communities from the Mississippi River.

- While not directly impacted by operation of the locks and dams, the trails along the river are some of the region's busiest. The trails provide significant views that attract visitors to use the trails. If the view of the river below changes significantly it may impact the visitors. This study should assess if a change in river character and a subsequent change in viewsheds affect recreational use by trail users.

Fundamental Resources and Values

Every unit of the National Park System develops a Foundation Document to provide basic guidance for planning and management decisions. A primary benefit of developing a foundation document is the opportunity to integrate and coordinate all kinds and levels of planning from a single, shared understanding of what is most important about the park. For its Foundation Document, the Mississippi NRRA identified the following fundamental resources and values:

- Cultural and historic sites that owe their national significance to their presence along the Mississippi River.
- Economic resources supported by the Mississippi River in the NRRA that are integral to the nation's economy.
- Collaborative relationships with governments, private sector organizations, non-profits, schools, and individuals that help the park to achieve its purpose.
- Healthy aquatic ecosystems that provide for a rich and diverse assemblage of fish, mussels, macro-invertebrates and other species, as well as the opportunity for scientific study.
- Healthy terrestrial ecosystems that provide for a rich and diverse assemblage of plants and animals, as well as the opportunity for scientific study.
- Birds that rely on the Mississippi River Flyway in the NRRA to provide nesting, resting and feeding habitat.
- Scenic views that allow people to experience the distinctive landscapes of the NRRA.
- Outdoor recreation opportunities and experiences that connect visitors with the river and its natural places, its cultural and historic sites, and its scenic vistas.
- The presence of bluffs, caves, waterfalls, and fossil beds that demonstrate the unique geologic character of the Mississippi River in the NRRA.
- Water Quality – Clean water that supports human use of the Mississippi River and vibrant ecosystems in the NRRA.

The NRRA will be reviewing the USACE Disposition Study and Environmental Assessment with these fundamental resources and values in mind and hopes the USACE considers these resources while conducting the study.

Site Resources: Land, Infrastructure and Water

As we understand it, the holdings of the Corps of Engineers at each site include the assets listed below. If we are missing something, please let us know.

- Lower St. Anthony Falls: Lock, dam, guidewalls, 3 dolphins, and access roads on each end.
- Lock and Dam 1: Locks, dam, guidewalls, bluff retaining walls, road, and land. Does the USACE own the hydroelectric plant powerhouse, just the base or dam portion, or both? We understand the USACE also holds 326 acres of flowage easements in Pool 1.
- Meeker Island Lock and Dam: Did the USACE fully dispose of the Meeker Island Lock and Dam land and infrastructure? The lock ruins are still present along the east bank, the bear traps gates lie on the west side under sand, and the partially demolished dam lies under Pool 1.

Since Lock and Dam 1 was built before the National Environmental Policy Act, it received no environmental review. In considering the cumulative impact of its alternatives, will the USACE need to consider the natural river as the baseline for determining cumulative impacts?

We appreciate your time to review our comments and questions on the scoping phase of the Disposition Study and look forward to your responses and continued collaboration on the Mississippi River.

C.2 Local Government Organizations

C.2.1 City of Minneapolis

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December 16, 2022

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St. Paul, Minnesota 55101
[redacted]

Dear Mr. Tallman,

Thank you for the opportunity to comment on the scope of the Lower St. Anthony Falls and Lock & Dam #1 Disposition Study.

The significance of the Mississippi River to the history and culture of this land cannot be overstated. The river shaped the City of Minneapolis by providing transportation, generating power, and facilitating commercial and industrial development. Minneapolis sits on Dakota land and the river has been - and continues to be – culturally and spiritually significant to Dakota people.

Today the iconic river remains a defining feature of Minneapolis and is as critical as it has ever been. Closure of Upper St. Anthony Falls Lock and Dam in 2015, which ended commercial navigation above the falls, has hastened the transition from industrial to recreational uses and elevated discussion about ecosystem restoration.

The City's comprehensive plan, *Minneapolis 2040*, includes the scenario to "Explore dam removal to restore natural flow and wildlife habitat on the Mississippi River. Identify support for displaced recreational activities and strategies to offset the potential reduction in hydroelectric power production." (Policy 70 Ecology & Habitat, Action Step). We want to explore this scenario while also considering whether there's an appropriate ongoing role for this infrastructure and the Army Corps of Engineers.

For each chapter in the City's story, the U.S. Army Corps of Engineers has been a critical partner. We appreciate the opportunity to collaborate with you to ensure the Disposition Study will provide the information needed to advise important decisions ahead.

The City supports a robust evaluation of the environmental, social and economic impacts of all the alternatives. Attached, please find additional comments on the scope of the Disposition Study.

Sincerely,

Mayor Jacob Frey,
City of Minneapolis

Minneapolis Comments on Scope of Disposition Study for Lower St. Anthony Falls and Lock & Dam #1

Future Conditions of the River

The U.S. Army Corps of Engineers (USACE) will look at a number of alternatives for this infrastructure including full or partial disposal, modification, removal, and the potential to serve a new purpose such as ecosystem restoration. The study will also include a combination of these alternatives. For each scenario we would like to understand the future characteristics of the river.

Questions about future conditions of the river include- projected water depth and speed by season and impacts of large rain events or during snow melt. What would the river's characteristics be? Rapids? Pools? How would water flow? Is there a flooding risk? What is the impact of old channels that have been dredged and what happens over time after dredging has ceased? Would USACE potentially take actions to establish a more natural condition? Or make other modifications to the riverbed? Will some scenarios cause oxbow lakes and/or potentially create new islands? What is the impact to shoreline and potential for erosion under these different scenarios? Does any scenario impact slope stability?

This information is required to address the questions below about the opportunities or concerns presented regarding recreation, habitat and wildlife, safety, culture, and infrastructure and will advise whether there's a federal interest in continuing to own and operate the lock and dams.

Safety & Emergency Response

Understanding the conditions of the river and surrounding land and bluffs under different scenarios will be useful to the Minneapolis Fire Department and other partners. The study should consider whether the water would be navigable to rescue boats operated by the Minneapolis Fire Department and the Hennepin County Sheriff. The needs and means to provide safety in the river corridor may change resulting in new capital investments and new training requirements. Conditions may also affect options for bridge inspection and repair.

Recreational Opportunities

For each scenario we would like to understand the types of recreation that may be possible or excluded by the conditions. This includes recreation like boating, tubing, rowing, whitewater rafting, hiking, biking, fishing, and birdwatching. The Mississippi is currently an attraction for residents and visitors and important part of our local economy. Enjoyment of the river contributes to a quality of life that draws people to live in the Twin Cities and is critical to tourism. The river is the primary feature of two Minneapolis Park and Recreation Board (MPRB) Parks - Central Mississippi Riverfront Regional Park and the Mississippi Gorge Regional Park and of course, the National Park Service's Mississippi National River & Recreation Area.

For many, viewing the river and our unique river gorge from the Grand Rounds National Scenic Byway, bridges or other vistas is a source of enjoyment and therefore, understanding the appearance of the river throughout the year is important. MPRB has requested illustrations of the various conditions and we support that request.

Historical & Cultural Significance

The Mississippi River has played a critical role in the City's development and therefore there are many historically designated properties along the river. See the Mississippi River Corridor Critical Area (MRCCA) plan for a description of properties and discussion of potentially historic resources. *See* MRCCA, A-43. Please also see other cultural resource studies that discuss historic resources relative to the National

Register of Historic Places. It will be important to identify the historic properties according to the regulations under Section 106 of the National Historic Preservation Act in 36 CFR Part 800 that are within the boundaries of the study.

We would like the study to address the ruins of Meeker Island Lock & Dam - not only in terms of historic significance - but how remains of that infrastructure may impact the flow and use of the river in different scenarios and the potential to remove or modify those structures.

The river includes sites that are culturally and/or spiritually significant to Dakota people including sacred locations such as Owámniyomni (St. Anthony Falls), Wita Wanagi (Spirit Island) and Bdote where the Mississippi and Minnesota Rivers meet. USACE has expressed its intention to engage Tribal Nations in this process. It will be important to engage the diverse Native community, including sovereign Tribal Nations, urban Indians and those in exile.

Ecology & Environment

The City's comprehensive plan includes a goal to "Explore dam removal to restore natural flow and wildlife habitat on the Mississippi River… ". In each scenario we would like to understand the potential impact on the existing environment as well as the potential to restore native wildlife and habitat and improve water quality. The alternatives to be studied by USACE already include, "potential opportunities for the locks and dams to serve a new purpose such as ecosystem restoration." We will be interested in those findings. How would non-native species like invasive carp be affected in these scenarios, and what might that mean for the ecosystem?

In each scenario we are interested in potential impacts to water quality and expectations about sediment deposits. Regarding sediment that has built up behind Lock & Dam #1, we would like to know how that would be managed. We would like information about the conditions of the sediment, whether it is contaminated, and how contaminated soils would be addressed.

Ownership & Authority

It will be helpful for the study to show land ownership or riparian rights in the study area and discuss how "new" land would accrue. This may be increased shoreline or new islands, for example. There are many stakeholders in the river corridor and some with overlapping jurisdictions. Identifying key stakeholders and their legal rights or responsibilities will be helpful - particularly in the vicinity of USACE infrastructure.

Infrastructure Impacts

The City is interested in the impacts of each alternative upon infrastructure along the river. For example, the potential for scouring of bridge piers or lowered elevations of the riverbed exposing more infrastructure. Stormwater outfalls that deposit into the river may no longer reach the river without significant reimagining and reengineering. There could be significant cost to re-evaluate and adapt public infrastructure. Are there federal resources to assist with costs?

The City will work with USACE to ensure sufficient detail is available about city infrastructure including stormwater and drinking water infrastructure. Bridges in the project area, listed below, are owned by various entities. Except for the 35W Bridge, all have one or more piers in the river.

- The Stone Arch Bridge owned by MnDOT
- 35W, MnDOT

- 10th Avenue, owned by Minneapolis. A large-diameter drinking water transmission main runs under the river just downstream of this bridge.
- Bridge Number 9 owned by Minneapolis
- Washington Avenue bridge owned by Hennepin County
- I-94 owned by MnDOT
- Franklin Avenue, owned by Hennepin County. This bridge has a large-diameter Minneapolis drinking water transmission main suspended underneath the bridge.
- Short Line owned by Canadian Pacific Railroad
- Lake Street owned by Hennepin County
- Ford Parkway owned by Hennepin County

There are public and private entities that divert water from the river and/or deposit water into the river. We would like to understand any impacts to this infrastructure. For example, A Mill Artist Lofts is a property of interest. Some scenarios studied could affect the generation of hydropower. In those cases, it would be helpful to quantify the effect in terms of net change of electricity produced and impacts on the producer or end-user.

It will be very important to understand how different scenarios relate to the current uses and plans for Upper St. Anthony Falls including potential impacts to infrastructure and surrounding land. The infrastructure at the Upper Lock serves many critical functions including maintaining water levels in the Upper Pool where water is drawn to be treated for drinking water. There are numerous important plans and activities in this vicinity including *The Falls Initiative.*

A Complete Picture

For each alternative, it will be helpful to look at the opportunities and challenges as a whole to do a cost-benefit analysis. This would include “costs” that may not be easy to quantify such as the ongoing impact to wildlife and habitat of maintaining the current infrastructure. Likewise, there are “benefits” that may be difficult to quantify such as new recreational opportunities that could improve resident health and well-being. The scenarios to be studied include major changes to the operation and/or maintenance of this infrastructure and having the most comprehensive information possible about the short-term and long-term costs and benefits will be critical to inform this discussion.

C.2.2 Metropolitan Council

December 16, 2022

Clayton E. Tallman, District Engineer
U.S. Army Corps of Engineers | St. Paul District
ATTN: Regional Planning and Environmental Division North
332 Minnesota Street, Suite E1500
St. Paul, Minnesota 55101
[redacted]

RE: Comments regarding the Lower Saint Anthony Falls and Lock/Dam 1 Disposition Study

Dear Mr. Tallman:

This purpose of this letter is to provide comment as per requested by your agency for the development of the planning scope for Lower Saint Anthony Falls and Lock/Dam 1. Facility changes to these structures would have significant impacts to regional services and amenities which are both provided by the Metropolitan Council (Council) itself and our partner communities and agencies.

Changes to the Mississippi River in terms of flow and scour in the reach below Lock/Dam 1 could significantly impact the wastewater conveyance where it crosses the river. The pipelines at the crossing provide service for nearly 700,000 residents of the Twin Cities. Protection or replacement of the wastewater facilities would have a significant cost impact to the Council and its rate payers.

Numerous regional parks and trails line the Mississippi River in the Twin Cities Metropolitan Area, and these lands are owned and managed by Regional Park Implementing Agencies. Together, hundreds of millions of dollars have been invested in these treasured regional park and trail units that are at the core of the region's identity. What are the most likely impacts to these lands and amenities? What will the riparian landscape look like throughout the corridor if these lock and dam structures are removed or altered? How will water levels change? The Council requests the US Army Corps of Engineers (USACE) better visualize and/or illustrate the most likely future states of the river corridor after the removal of one or both dams.

Further, if management of the lock and dams were transferred to a new entity (not the USACE), the Council requires assurance the new entity would have the qualifications and capacity to operate and maintain the two dams into the future. There would need to be requirements placed on the entity to ensure there would not be a possibility of defaulting on their responsibility to keep the structures in good operating order.

As the process to study the disposition of Lower Saint Anthony Falls and Lock/Dam 1 progresses through these early stages, the Council appreciates the opportunity to continue dialogue and comment to help inform the scope and findings of the study.

Sincerely,

Emmett Mullin | Adam Gordon

Emmett Mullin
Regional Parks Manager

Adam Gordon
Interceptor Engineering Manager

C.2.3 Minneapolis Parks & Recreation Board

Minneapolis
Park & Recreation Board

Administrative Offices
2117 West River Road North
Minneapolis, MN 55411-2227

Northside Operations Center
4022 1/2 North Washington Avenue
Minneapolis, MN 55412-1742

Southside Operations Center
3800 Bryant Avenue South
Minneapolis, MN 55409-1000

Phone
612-230-6400

Fax
612-230-6500

www.minneapolisparks.org

December 7, 2022

Clayton E. Tallman, District Engineer
U.S. Army Corps of Engineers | St. Paul District
ATTN: Regional Planning and Environmental Division North
332 Minnesota Street, Suite E1500
St. Paul, Minnesota 55101
[redacted]

RE: Comments regarding the Lower Saint Anthony Falls and Lock/Dam 1 Disposition Study

Dear Mr. Tallman:

This letter is written on behalf of the Minneapolis Park and Recreation Board (MPRB) and addressing scoping relative to the disposition study for the Lower Saint Anthony Falls and Lock/Dam 1. The MPRB is a semi-autonomous unit of government responsible for the ownership, programming, maintenance, and perpetuation of more than 6800 acres of parkland within the City of Minneapolis, including parks bordering the Mississippi River near the Lower Saint Anthony Lock and Dam and Lock and Dam 1.

The MPRB understands comments are intended to address scoping of the work to be undertaken in the disposition study. Staff have attended public meetings where core components of the already prescribed scope were demonstrated and have reviewed other materials provided by the US Army Corps of Engineers (USACE). Our intention in offering the comments in this letter is to begin framing a position relative to disposition and to encourage a finer grained consideration of disposition than we understand is available today.

To begin, we are hopeful that the scope can include some demonstration—beyond hydrographic modeling—of the conditions of the river should disposition lead to removal of structures. While there might be intrinsic desire to return the river to its natural state through structure removal, it will be helpful for the USACE to prepare illustrations of varying locations and flow conditions as a means of telling a pictorial story of that process. As the river is the core experience of park users in the Central Mississippi Riverfront Regional Park and the Mississippi Gorge Regional Park—both being park assets of the MPRB, helping our park users understand the potential evolution of the river is critical to the engagement the MPRB would pursue relative to the USACE's disposition initiative. The MPRB strongly encourages the USACE to, in the process of preparing the disposition study, to develop easily understood graphic depictions of potential future conditions should structures be removed.

The MPRB is also interested to know more about the disposition of accretive lands should structures be removed. Today, the borders of the MPRB's Mississippi River parks are the river's edge. Should structures be removed resulting in "new" lands along the river, the MPRB would want the accretive lands to become part of its bounding regional parks. To introduce a different land-owning entity would surely cause confusion among park users, who may be encounter varying direction in park use and operations between park-owning entities as they experience the river in Minneapolis. Relative to scoping for the disposition study, the MPRB would encourage the USACE to consider accretive lands to be adjoined to lands of the existing riparian landowner.

It was noted during one of the public meetings that a disposition would occur in whole, with lands and structures considered as a single package. While the MPRB would be interested in the accretive lands resulting from a change in the way the river is controlled, it would not have the resources necessary to acquire and perpetuate—or remove—any vertical construction currently operated by the USACE or others. To the extent it can be accommodated, consideration of separate dispositions of accretive lands and vertical construction components would be encouraged by the MPRB.

The Mississippi River is presently a managed waterway through the City of Minneapolis and the watercourse provides a means of access for maintenance and inspection of riparian lands and bluffs, storm sewer outfalls, and other public infrastructure. Without such access, regular and ongoing maintenance and monitoring could be made significantly more difficult. The MPRB requests the USACE to consider impacts of potential restricted maintenance access by water to adjacent lands and infrastructure.

While the current scoping identifies an assessment of social, environmental and economic conditions, they are likely to be considered as separate and distinct factors. In fact, the MPRB believes a better approach is a comparative assessment of these conditions in their extant context to any number of future conditions. Such a triple bottom line assessment of alternatives offers a truer and more holistic picture of the potential change and its impacts, all defined equally as costs and benefits and made easily comparable as a result. The MPRB encourages the application of tools such as Envision and AutoCASE to more fairly and fully assess impacts related to social, environmental, and economic factors.

Finally, the MPRB is interested in understanding any cumulative or reciprocal effects on the Lower St. Anthony Falls Lock and Dam and Lock and Dam #1 should a disposition lands at the Upper St. Anthony Falls Lock occur. Essentially, the MPRB is asking that the USACE provide context for the subject disposition in the context of any planned disposition, especially since it seems the dispositions occupy nearly similar geography in the context of the Minneapolis Park system.

The MPRB appreciates the opportunity to offer these comments as the USACE begins its work on the disposition study. We look forward to continued dialog with the USACE and others as that process unfolds.

Sincerely,

Meg Forney

Meg Forney
President, Minneapolis Park and Recreation Board of Commissioners

C.2.4 Minnesota Mississippi River Parkway Commission

Minnesota Mississippi River Parkway Commission
56 33rd Avenue South, #283 • St. Cloud, Minnesota 56301
651-341-4196 • info@MnMississippiRiver.com

December 13, 2022

Col. Eric Swenson, District Engineer
U.S. Army Corps of Engineers St. Paul District
180 Fifth Street East, Suite 700
St. Paul, Minnesota 55101-1678

Dear Colonel Swenson,

This letter is provided to share information about the Minnesota Mississippi River Parkway Commission's (Commission) mission and how that mission relates to the potential opportunities and impacts coming from the Lower Saint Anthony Falls Lock and Dam and Lock and Dam No. 1 Disposition Study.

As established under Minnesota Statute 161.1419, the Commission's mission is to promote, preserve and enhance the resources of the Mississippi River Valley and to develop the highways and amenities of the Great River Road, which, in February 2021, received All-American Road status. The Commission promotes, supports, and advances actions, responsibilities, procedures, controls, operational practices, and strategies to maintain the intrinsic archaeological, cultural, natural, historic, recreational, and scenic qualities that support National Scenic Byway and All-American Road Designation. The Commission's interest in the Disposition Study relates to these intrinsic qualities defined by the Federal Highway Administration as the basis for the designation.

The Great River Road/All-American Road runs adjacent to the Mississippi River from St. Anthony Falls to the Minnesota River confluence at Fort Snelling. At St. Anthony Falls, the Mill City Museum is a designated Great River Road Interpretive Center as is Fort Snelling, which is a National Historic Landmark. The St. Anthony Falls Historic District features the Pillsbury A and Washburn A Mills, both of which are National Historic Landmarks, and the James J. Hill Stone Arch Bridge, a National Engineering Landmark. Given their connection to the history of Mississippi River navigation, the Lower St. Anthony Falls Lock and Dam and Lock and Dam No. 1 have been determined eligible for the National Register of Historic Places. With all the planning and projects already built to turn the St. Anthony Falls riverfront into a world-class visitor destination, the opportunities to inform and educate visitor about the Great River Road are immense.

The Commission encourages your consideration of comments submitted or being submitted by our member agencies (noted above) during the Scoping Phase as to all the matters and issues that the Corps should address in your study, including in the National Environmental Policy Act report. The more comprehensive and complete the Corps' studies are, the better the public, other agencies and the Commission will be able to understand and weigh in on the future of the Mississippi River in the heart of the Twin Cities. We also ask that you consider how your studies, recommendations and decisions may affect the Great River Road's intrinsic qualities. If you have questions or would like additional information, please contact the Commission office at 651-341-4196. Thank you for your consideration.

Sincerely,

DMSenjem

Senator David Senjem, Chair

C.2.5 St. Paul Safety & Inspections

SAINT PAUL
SAFETY & INSPECTIONS

DEPARTMENT OF SAFETY & INSPECTIONS (DSI)
ANGIE WIESE, DIRECTOR

375 Jackson Street, Suite 220
Saint Paul, MN 55101-1806
Tel: 651-266-8989 | Fax: 651-266-9124

December 20, 2022

RE: U.S. Army Corps Lock and Dam Disposition Study

The City of Saint Paul has reviewed the information available as part of the US Army Corps' public comment period regarding the future of the locks and dams on the Mississippi River. The Lock and Dam study being conducted by the Corps is looking at the removal of dam infrastructure completely with in the urban core of two major metropolitan cities along the largest and most quintessential river in the United States. Lock and Dam #1 (Ford Dam) has been a feature on the stretch of the Mississippi within Saint Paul, since its construction in 1917. We appreciate our relationship with your agency and the opportunity to participate in the development of the scope of the future Lock and Dam disposition study.

The City of Saint Paul understands that this is just the beginning in a long process to look at the locks and dams within the Twin City metro area and whether the U.S. Army Corps will seek congressional approval to disperse the locks and dams. Saint Paul's comments are focused on Lock and Dam #1 (Ford Dam) as that is the only structure with the city limits of Saint Paul. The U.S. Army Corp's study should review the multiple of impacts of removing the lock and dam but not be limited to the following.

- The Corps is directed by federal executive order to include tribes in its process in a meaningful and timely way. We expect the Corps to consult with tribes early and often throughout the disposition process, provide funds to tribes to cover the direct costs of their participation in this study, publish tribal engagement findings, and allow adequate time and notice for full tribal participation.
- The City of Saint Paul owns and maintains numerous storm water outfalls that discharge into the Mississippi River at or near current river levels. The study should review the impacts to these outfalls in regards to design and cost of modifications to these outfalls to protect both City infrastructure and to protect from environmental impacts.
- The two counties of Hennepin and Ramsey own various bridges that cross the Mississippi River. The City of Saint Paul helps with management of these bridges. The Corp's study should review the impact of new river hydrology to bridge piers and abutments and include changes design and maintenance practices that may need to be accounted for. The County also owns infrastructure that handles stormwater runoff that discharges to the river, similar review should be conducted for County owned stormwater outfalls.
- A complete study of the Mississippi river's new hydraulics and hydrology patterns. Removing Lock and Dam will change the nature of the river's flow and the study should review what impacts this will have both upstream and downstream. How will this new hydraulic grade and elevations of the river effect Public owned parcels and infrastructure along the banks of the

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Mississippi including the existing levee/floodwall system, proposed site of the River Learning Center at the Watergate Marina? How will the new river dynamics effect the ability to meet the needs of the shipping industry at the ports sites along the river in St. Paul, and other commercial uses located in the floodplain? Will new flow patterns effect polluted hotspots like Area C at the Ford Dam or historical dump site at Pigs Eye Lake? Will new structures be needed to protect existing infrastructure that is currently protected by the lock and dam? Account for different scenarios where only certain dams and locks are removed and other remain.

- The above concerns and questions must also be address in regard to the City of the City of Saint Paul's responsibilities s a participant in the National Flood Insurance Program.
- The Study should look to answer specific Park questions related to Saint Paul Parks;
    - **Meeker Island Dog Park** (Dog park, nature trail)
        - What would be the water levels be if dam(s) were removed
        - What is the effect on the existing lock structure?
        - What would the OHWL/Flooding levels be?
    - **Crosby/Hidden Falls** (Marina, boat launch, picnicking)
        - What would be the water levels be if dam(s) were removed?
        - Boat launch may need to be reconstructed.
    - **River Learning Center**
        - How much will the water levels be impacted?
        - What impacts would there be to River Learning Center?
        - Specifics about impacts to water levels?
        - Will there be less bounce in the river if the dam(s) are removed?
        - We need to maintain or increase recreational access thru the river corridor.
        - Prepare study for RLC
        - Can and how will the marina be maintained?
    - **Lilydale**
        - How will levels of Pickerel Lake be affected?
        - What will be the impact to the boat launch?
        - Are there any impacts to the swing bridge?
        - Will lower water levels leave Historic stone bridge high and dry?
    - **St. Paul Yacht**
        - Will lower water levels leave access to St. Paul Yacht harbor inaccessible?
    - **Harriet Island**
        - Will rip rap need to be extended or wall foundations be exposed?
    - **Upper Landing Park**
        - Will there be any impact to wall foundations due to lower water levels?
    - **Raspberry Island**
        - Will access to water from Minnesota Boat Club need to be extended to lower water levels?

SAINT PAUL
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        - Will stairs at end of Raspberry Island fall short of lower water levels?
        - We should have cross sections downtown with river?
    - **Lambert's Landing**
        - Will port be able to be maintained?
- The Corps should study and layout plans for the need for sediment removal and mitigation. Decades of sediment accumulation have taken place behind Lock and Dam #1, mostly likely along with contaminates and years of pollution accumulation. The study should layout the methods for analyzing and quantifying the amount sediment and the level of contamination. The study should layout the need and methods for sediment removal and disposal to protect downstream waters.
- If islands and/or additional shoreline were to form due to dam removal or other alternatives, who would own and manage that land? Do any easements exist that would apply to these newly-exposed areas?
- The Corps should study and layout plans for the need for sediment removal and mitigation. Decades of sediment accumulation have taken place behind Lock and Dam #1, mostly likely along with contaminates and years of pollution accumulation. The study should layout the methods for analyzing and quantifying the amount sediment and the level of contamination. The study should layout the need and methods for sediment removal and disposal to protect downstream waters.
- The Corps should look into the effect of leaving the dams in place long term without proper maintenance until a decision has been made and/or until removal or long-term owner can be determined. Without continual upkeep and maintenance, the Lock and Dam will become an eyesore and blighted structure along the river and limited maintenance will increase the risk of failure. One of the areas of concern that the Corps needs to address in the study is the structural integrity of LD1. Which was categorized under the Dam Safety Action Classification as "2 – High Urgency of Action" due to an elevated risk of failure caused by erosion that would be virtually impossible to detect with sufficient notice for intervention. However, the dam was subsequently reclassified to "4 – Low Urgency of Action" not because the erosion and structural integrity issues were resolved, but because failure of LD1 would likely not cause loss of life and economic consequences are low to moderate. The structural integrity of LD1 has profound implications for any future owner and suitability of the structure for alternative uses. Given this information, the Corps needs to provide additional details about the risk of dam failure within the 50-year planning period and explain how dam failure would impact recreational use of the reservoir.
- The study should review federal guidelines changes that may occur in relation to the river and change in river status. Would the OWHL level change? Would the sections upstream of Saint Paul no longer be considered navigable, impacting barge access for infrastructure repair and replacement? These changes would change the review authority of various government agencies.

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- The study should analyze the impacts to existing recreation along the Mississippi and what future opportunities for recreation if the lock and dam is removed.
- The study should analyze the impact to flooding along the Mississippi. Will flooding events increase or decrease? If the Corps chooses to leave Lock and Dam #1 in place, could the Corps initiate pool drawdown in the winter to prepare for the spring thaw? Could modifications be added to accommodate possible drawdowns for flood migration.
- The Corps must initiate an Environmental Impact Statement (EIS). EIS is required when the Corps considers "[p]roposed major changes in the operation and/or maintenance of completed projects.", per the Corps' procedures for implementing NEPA. The very nature and purpose of the Disposition Study is to consider a "major change in the operation and/or maintenance of a completed project." As such, the Corps must automatically initiate the Environmental Impact Statement process. Due to the Given the persistent impacts of impounding the Mississippi River, the Corps must conduct an EIS to evaluate the ecosystem consequences of a decision to retain the Lower St. Anthony Falls Lock and Dam and Lock and Dam 1.
- Again, the study should also consider potential impacts to existing floodplain development approved under requirements of the National Flood Insurance Program, as well as impacts to the future ability of property owners to make continued investments in existing properties.

The City of Saint Paul appreciates the opportunity to provide input at this point in the scoping process and looks forward to working with the U.S. Army Corp to determine the best course of action in regard to the locks and dams on the Mississippi River.

Sincerely,

Andrew Hogg

Andrew Hogg
City Water Resources Coordinator
Department of Safety and Inspections

cc:

C.3 Non-Government Organizations

C.3.1 American Rivers and Friends of the Mississippi River

December 13, 2022

District Engineer, U.S. Army Corps of Engineers, St. Paul District
ATTN: Regional Planning and Environment Division North
332 Minnesota St., Suite E1500
St. Paul, MN 55101

Submitted via email to MplsLocksDisposition@usace.army.mil

Re: Statement of Interest for Lower St. Anthony Falls Lock and Dam and Lock and Dam 1

To Whom It May Concern:

The provisions of Section 216 of the Rivers and Harbors Act of 1970, as amended, provides authority for the Corps to determine whether a water resources development project operated and maintained by the Corps should be deauthorized and if associated real property and government-owned improvements should undergo disposal. We also understand that, as part of the disposition study, the Corps will consider whether there is a stakeholder interested in taking ownership of the project. Our organizations express interest in establishing a trust to take ownership of or raising requisite match funds for removal of Lock and Dam 1, and Lower St. Anthony Falls Lock and Dam, and the associated real estate at those sites, should the study determine that removal of the dams is in the public interest.

American Rivers protects wild rivers, restores damaged rivers, and conserves clean water for people and nature. Since 1973, American Rivers has protected and restored more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects, and an annual America's Most Endangered Rivers® campaign. Headquartered in Washington, DC, American Rivers has offices across the country and more than 275,000 members, supporters, and volunteers. The Upper Mississippi River is one of 11 priority river basins where American Rivers concentrates the bulk of its activities. In the basin, we are working to reform the management of the Mississippi River and reconnect rivers to their floodplains.

American Rivers has a long history of river restoration, particularly removal of dams that have outlived their usefulness and pose environmental and safety hazards. More than 1,400 dams have been removed around the country, and we have provided direct technical assistance or managed the removal of more than 240 of those dams. We are experts in developing partnerships, obtaining permits, creating ownership entities (such as trusts and non-profit corporations), mitigating risk, and raising funds necessary for successful dam removal projects of all sizes.

Friends of the Mississippi River (FMR) was established in 1993 to be the citizen, community and environmental voice for the river in the Twin Cities region. Over nearly 30 years, we have grown to 16 board members, a 12-member council of advisors, 23 staff, 2,500 members, and over 6,000 annual volunteers, event participants, members, and advocates.

FMR has built a strong reputation for taking an inclusive, place-based, and strategic approach to protecting and enhancing the health of the Mississippi River and its watershed as well as protecting the many assets the river brings to our region. FMR's four program areas focus on water quality and watershed health, land protection and restoration, community education and engagement, and land use and planning. FMR is also leading and participating in broad coalitions to not only protect our local river and watershed but also to produce replicable results and models that can be used to address the larger water quality and land use issues facing the Mississippi River and its watershed on a basin-wide level.

We are aware that this is a long process with many steps. This letter serves as an expression of interest only and creates no contractual obligation, and either party may cease pursuit of this matter at any time.

Please contact our staff regarding this matter: Olivia Dorothy, [redacted] at American Rivers, and Colleen O-Connor Toberman, [redacted]

Sincerely,

Thomas Kiernan

Tom Kiernan, President and CEO
American Rivers

Whitney L. Clark

Whitney L. Clark, Executive Director
Friends of the Mississippi River

C.3.2 Friends of Pool 2

Keenan, Sierra L CIV USARMY CEMVP (USA)

From:	Greg Genz [redacted]
Sent:	Monday, December 19, 2022 2:11 AM
To:	DLL-CEMVP MPLS LOCKS Disposition
Subject:	[Non-DoD Source] MPLS Locks Disposition

To Whom it May Concern,

We, the Friends of Pool 2's main concern is that this Disposition Study is proceeding without knowing the potential costs. How can the COE make any decision on turning over the property when the cost of any entity assuming ownership/control is unknown. If any party would take on the ownership of Lock and Dam 1 and want to remove it, there is a potential cost of sediment removal being $200 million dollars.
Friends of Pool 2 wants to be assured that the approximate 2 million cubic yards of potentially contaminated sediment does not end up washing down into Pool 2. We have enough contaminated sediment fouling and clogging our waters. We don't feel that the COE can make a disposition without the costs. Both monetary and environmental.

Thank you for your attention to this matter.

Greg Genz
Vice President
Friends of Pool 2

C.3.3 Macalester College

ENGAGEMENT MATTERS: Public Understandings of River Infrastructure

Report submitted to the U.S. Army Corps of Engineers regarding their Upper Mississippi Disposition Scoping Process

DECEMBER 2022

ACKNOWLEDGEMENTS

This report was written by Dr. Roopali Phadke, with assistance from Nili Barnoon, Rebecca Driker-Ohren, Romeo Gomes, Zella Lobo, and Amber Wiedenhoeft.

We would like to thank our collaborators at American Rivers, Friends of the Mississippi River, Mississippi Park Connection, National Park Service, National Parks Conservation Association, Paddle Bridge and the Saint Paul Public Library for their partnership. We extend our gratitude to historian Dr. John Anfinson for sharing his knowledge and expertise. Thanks also to Kalen Keir, Tom Reiter and David Wheaton for their photography.

We appreciate that staff from the St. Paul District of the Army Corps of Engineers have collaborated with us throughout our study period.

OUR PROJECT

The U.S. Congress charges the Army Corps of Engineers to conduct disposition studies to determine whether a project that they operate and maintain should be deauthorized and ultimately disposed of. The Corps is in the midst of conducting disposition studies from coast to coast. This process includes gauging public opinion through hearings and public comments.

Since 2020, we have been examining the Corps' ongoing study of the Upper Mississippi, which includes the three uppermost locks and dams on the river (Upper St. Anthony Falls, Lower St. Anthony Falls and Lock and Dam 1). Beyond the Mississippi, we are examining the outcomes of disposition studies on other American rivers.

You can find out more information about our project, including our public opinion surveys and public arts projects, on our website: **https://sites.google.com/macalester.edu/disposition/home**.

This project is funded by the National Science Foundation (SES#1947152). If you have any questions about the research study, please contact Dr. Roopali Phadke, [redacted]

*Cover image from Paddle Bridge kayak tour of Lock and Dam 1.

I. INTRODUCTION

Throughout June and July of 2022, our research team collected 233 surveys from Twin Cities community members regarding their understanding of lock and dam infrastructure and their opinions on the future of the Lower Saint Anthony Falls Lock and Dam (LSAF L & D) and Lock and Dam No. 1 (L & D 1). Although this is a relatively small sample size, it exceeds the 199 public comments the Army Corps of Engineers received during their Upper Saint Anthony Falls Disposition Study comment period.

We collected these surveys during a series of walking, biking, kayaking, and boat focus group tours which included 3 community council tours, 2 BIPOC (Black, Indigenous and people of color) tours, and 1 youth-centered tour. Our team partnered with the Friends of the Mississippi River, National Park Service, National Parks Conservation Association, Mississippi Park Connection and St. Paul Public Library to broaden our outreach and the expertise offered to participants.

This report shares the insights we gained from hosting focus group tours and the conclusions we have drawn from post-tour participant surveys. We hope this will serve as guidance for the Corps' public engagement processes on future disposition studies, including the LSAF L & D and L & D 1 Disposition Study. In particular, we hope to highlight what we think are effective ways to prime public interest and knowledge on the topic. We also provide guidance on increasing the diversity and inclusivity of the Corps' engagement strategy.

II. METHODS & DEMOGRAPHICS

We had over 400 applicants for our 2022 public tours. We used diverse outreach methods for sharing information about these tours with the help of our partners. This involved distributing posters in public spaces including restaurants and corner shops, and posting to our social media pages and our partners' social media to communicate about our project, survey, and focus group tours. Across all tours, we aimed for inclusivity in terms of race, ethnicity, gender, sexuality, age, and knowledge about lock and dam infrastructure. We asked community members to provide demographic information on their tour request forms and combed through the data to carefully select as diverse groups as possible for each tour date.

We partnered with Friends of the Mississippi River (FMR) and Mississippi Park Connection to organize our BIPOC and youth tours because of their extensive experience, networks, and platforms for inviting BIPOC to events. FMR hosts a network of high school and middle school-aged students through their Environmental Stewardship Institute program. We also partnered with the Mississippi Park Connection and the Science Museum of Minnesota. Both organizations were hosting summer youth programs. These partnerships allowed us to develop tours that centered BIPOC and youth, who are usually excluded from these conversations, in a respectful and meaningful way.

During all our tours, we shared information about the history and function of the three upper Mississippi River locks and dams and the current disposition study. This helped participants imagine different futures for the Mississippi. This portion of each tour was important because it informed participants of the issues we eventually asked about in our survey at the end.

The demographic information we collected from community members who signed up for our tours showed us which communities we did and did not reach. We collected demographic information from tours between June 4th and July 27th, 2022, which included 9 public tours, 1 BIPOC-only tour, and 3 additional tours conducted by our partners at FMR for specific groups, including neighborhood associations from both sides of the river.

Figure 1. Participants engaging on our June 22nd boat tour and July 23rd bike tour.
Photo credits: David Wheaton (left) and Amber Wiedenhoeft (right)

Despite our very intentional efforts at reaching a more diverse audience for our tours, eighty percent of participants who provided demographic data identified as "Caucasian/White." Given the demographics of the Twin Cities, where 27% of the population identifies as people of color according to 2018 data, our tours lacked representative ethnic and racial diversity. This suggests the need for even deeper recruitment of participants. The age range of tour participants also favored an older demographic, with 48% of participants 56 years or older, 26.5% between 31 and 45 years, and 13.2% between ages 18 and 30. Over half of our participants identified as female (59.4%), with 39.6% male and 0.9% non-binary.

Our survey results also found that most tour participants frequently used the river. Sixty-three percent of participants said that they use the river at least several times a month and 28.6% use it several times a week. We know that those who are not river users have important points of view and should be part of the public engagement process. Finding those communities, and engaging with them intentionally, will require considerable effort.

Participants listed "hiking, running, and walking" (28.5%) and "biking" (18%) as the most common activities performed on or near the river. Other participants said they use the river for "rowing" (1.1%), "motorboating" (1.5%), and "fishing" (1.9%). These data suggest that our tours attracted individuals who wanted to join us to take part in the activities they regularly enjoy. To include different types of river-users, future tours could center on activities like fishing, birding, foraging, and rowing.

III. WHAT WE LEARNED

The surveys we conducted following each of our 13 focus group tours yielded important information about how to communicate with the public about locks and dams and disposition studies, and the most effective and inclusive ways to engage communities. We recognize that the Corps has the power to make important decisions about lock and dam infrastructure that will significantly impact surrounding communities for generations. It is vital that public engagement at this stage be as widespread and inclusive as possible.

a. Priming Engagement

For the public to meaningfully engage in disposition studies, it is important to provide foundational knowledge about the purpose of locks and dams, the Corps' current and potential future role in managing locks and dams, and other information that may impact public comments. Our survey results show that currently, accurate knowledge about the upper Mississippi locks and dams is not widespread among Twin Cities residents. Survey participants also shared what information they would find most helpful from the Corps in a disposition study public engagement process.

Each focus group tour included extensive background on the history and function of the locks and dams. After tours, we asked participants to name the authorized purpose of the infrastructure. Surveys show that members of the public continue to have uneven understandings of that purpose.

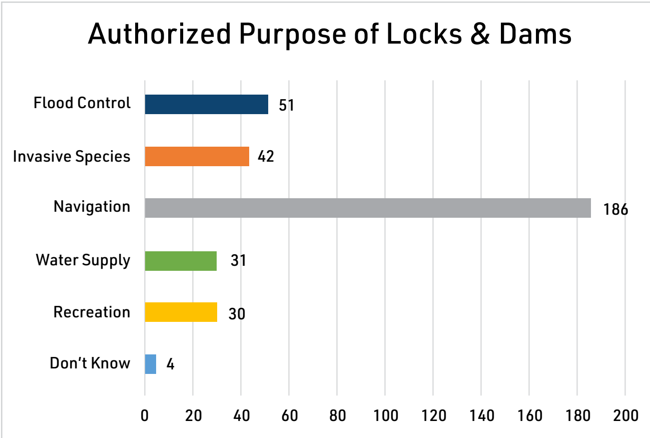
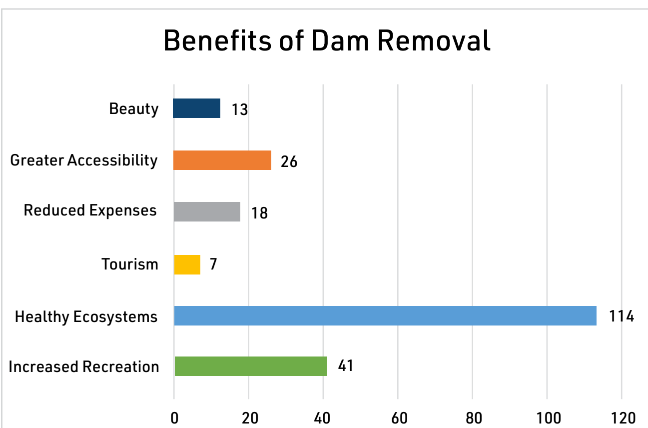


Figure 2. Authorized purpose of LSAF L & D and L & D No. 1 according to survey participants

Although we discussed that "navigation" was the original, congressionally authorized purpose on our tours, we were surprised that respondents did not select that answer. Forty-six percent of participants instead listed other purposes as primary, including flood control and water supply.



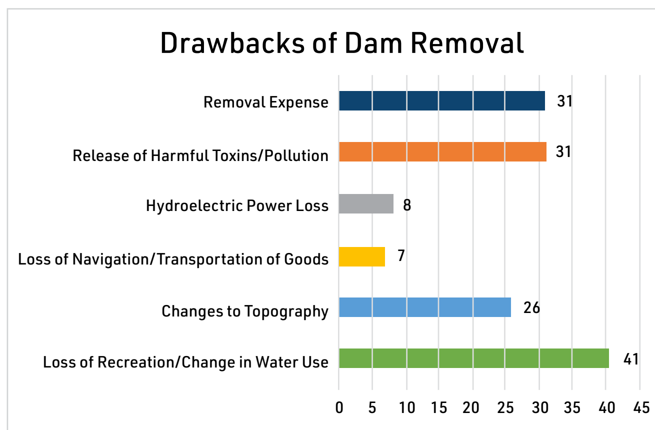


Figure 3. Benefits and Drawbacks of dam removal according to participants

The public's lack of understanding about the Upper Mississippi locks and dams may hinder their ability to meaningfully engage in disposition studies. This suggests a need for continued comprehensive public outreach and education.

The types of information survey participants thought would be useful to know prior to participating in a Corps disposition study provides guidance for topics the Corps can focus on in future research and community education. Of those surveyed, a large share of participants requested information about ecological impacts (26.4%) and about social and community impacts (21.3%). Tour participants also wanted to learn more about sediment toxicity, current and future costs of lock and dam maintenance, and the cost of dam removal.

Participants also told us what they thought the benefits and drawbacks to dam removal might be. This information can help the Corps understand what to prioritize in their public communication about lock and dam removal. As Figure 4 depicts, participants listed "Healthy Ecosystems," "Increased Recreation," and "Greater Accessibility" as a few of the benefits they saw for dam removal. They suggested "Loss of Recreation," "Release of Harmful Toxins," and "Removal Expense" as potential drawbacks to lock and dam removal.

While we see these as important topics to communicate to the public, we also found it notable that participants offered up a wider variety of drawbacks over benefits. In part, this might be explained by the fact that most of our participants were regular river users. As a result, it may be more difficult to imagine what a community may gain from removing the infrastructure, compared to the loss of what they know.

We suggest the Corps take steps to make it easier for the public to understand what a Mississippi River without these locks and dams would look like, including providing visual representations of future scenarios. The use of augmented and virtual reality could be particularly powerful in helping residents imagine a restored river.

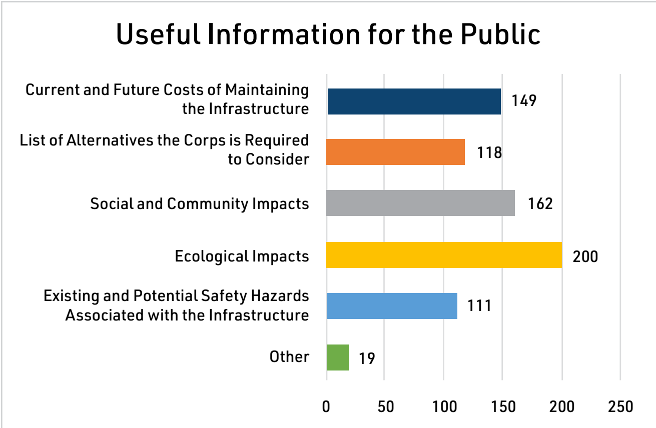


Figure 4. Information survey participants would find useful from the Corps

b. Engaging Diverse Communities

Engaging diverse communities in the Corps' disposition studies would ensure that Congress receives a recommendation that reflects input from those who will be impacted by their decisions. The Corps should take steps to reach a wider range of individuals, especially those who have historically been excluded from major decisions around infrastructure including BIPOC communities and youth.

Our research demonstrates that while the majority of our survey participants said they would participate in the current LSAF L&D and L&D 1 Disposition Study, only about half of the survey participants said that they knew about the study before engaging in our tours. Based on our team's previous research, we believe this percentage is relatively high. In summer 2021, our team collected 270 surveys at local river parks. When we asked this same question, we found that only 16.7% of people knew about the study. Our summer 2022 focus group participants likely belong to river-related groups that are following communications about the disposition study. The desire to participate, combined with the general lack of knowledge among most about the study process, suggests that the Corps' engagement methods should be more expansive.

Survey participants in our focus group tours suggested the best ways for the Corps to engage the public about the disposition study would be an online survey or an online public forum. The difference between the youth-only survey data and non-youth survey data is notable for this question. While only 7.5% of the non-youth-focused tour participants listed social media as the most convenient method for engagement, 16.1% of the youth we surveyed said that was the most convenient option.

Our survey results showed the tours we hosted helped people better understand the Mississippi and begin to imagine how the future river would look. The tours provided an opportunity to prime the public about the history of locks and dams and details about the disposition process. Many survey participants listed continued tours as a good way to engage the public.

While we recommend tours as an effective public engagement tool, each type of tour offers unique benefits. In summer 2022, we offered bike, boat, kayak, and walking tours. We found that walking tours were the most cost-effective and accessible. Although walking tours offer less interaction with lock and dam structures, they can reach the broadest audience with the fewest resources needed to organize them. Participants engaged the most with the river and infrastructure on boat and kayak tours, but they are the least cost-effective and require more planning and staff. By offering more walking tours, the Corps can educate the public about their work and receive feedback in an interactive environment.

Figure 5. Participants on our June 18th walking tour. Photo credit Amber Wiedenhoeft

Surveys strongly emphasized the importance of including Indigenous people in the Corps' public engagement process because of their historical and cultural ties to the river. Responses included one individual who said the Corps should, "Center indigenous voices, put their desires first, and provide for the consideration of how to materially support their goals" and another who shared: "I want Indigenous folks to have the most say - they care for better standards of the land, and water, have ancestral ties and are owed some sort of reparations for their forcible exile/ expulsion from the place."

Participants in our survey provided potential ways to engage these communities. They suggested the Corps should connect with community leaders and specific groups (tribes and groups, NGOs, and colleges and schools) and outreach at community events, cultural centers, and community hubs. Many shared that they should engage with communities directly by hosting educational tours, canvassing at community events and centers, and meeting with community leaders.

The Corps should also consider how the timing and location of their events create barriers for participation. Offering meals, daycare, transportation and translation services might encourage wider attendance at in-person events. Many government agencies are now also providing an individual monetary incentive for participation to show that they respect the time commitment involved.

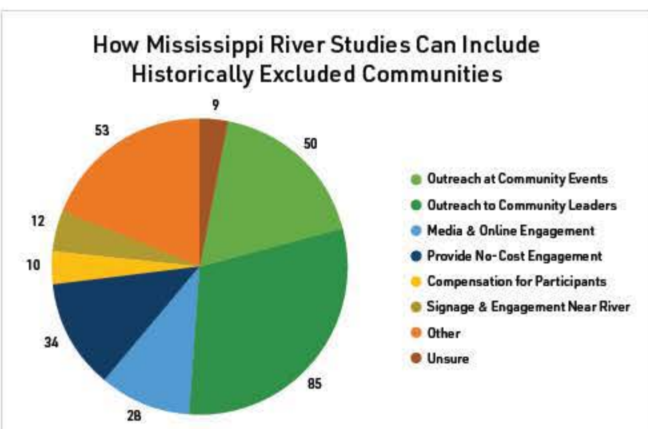


Figure 6. Increasing Outreach

IV. RECOMMENDATIONS

The focus group tours we hosted this summer, along with the post-tour surveys we collected, offer important insights into how the Corps can facilitate a more diverse and inclusive public engagement process. Below is a summary of our recommendations.

We recommend offering ***educational resources and public tours*** while collecting comments, and even after the comment period closes. Completion of the disposition study will take years, and we need to keep the public engaged and knowledgeable about the history and authorized purpose of the locks and dams. Continued access to the visitor centers and educational programs, like lectures, walking tours and public art, are vital toward this effort. If the Army Corps cannot staff these events, partnerships with the National Park Service and local nonprofit and educational groups might fill some gaps. We found walking tours inexpensive, accessible and able to accommodate large groups and provide close interaction with the river.

We encourage the Corps to present community members with ***visual representations*** of what a future Mississippi River might look like so they can better imagine the benefits and drawbacks of different scenarios. The National Parks Conservation Association has created a set of visualizations that could serve this initial purpose or serve as a baseline for additional images. Figure 7 includes one example. Additional images are available on the NPCA website at **www.npca.org/missriver**.

We recommend the Corps collect ***basic demographic information*** about who submits comments and attends public events. This information can be collected anonymously by providing those who submit comments a link to a survey. Demographic forms can also be provided when participants register at in-person or online events. Without this information, it is impossible to know who has and has not participated, and how to target future engagement.

We hope the Corps will prioritize ***intentional, inclusive, and diverse engagement opportunities,*** to collect additional information during the study process. It will be important to continue to build public interest and gather key stakeholder perspectives during the preparation of the study. This will ensure

Figure 7. Rendering of Lower St. Anthony Falls with lock and dam removed. Image credit LVBrown Studio

that there will be interest in the draft study when it is released. Our survey results show that each tour type we offered (i.e., walking, biking, kayaking, or boat) attracted individuals who were already committed or enjoyed that type of activity. Offering fishing or rowing events, for example, would engage new groups of people who have insight into those activities.

The Corps should provide ***online engagement*** opportunities. Survey results from both youth and adults suggested that many are interested in engaging with the Corps' study via online surveys or an online public forum. This would be particularly important as public health challenges are likely to surge in colder weather months, and outdoor conditions make travel to public events more challenging.

Finally, we urge the Corps to build partnerships with ***youth and youth-led organizations.*** We found that youth are deeply interested in thinking about the future river and have the capacity to participate and engage. While there may be limitations or concerns about working with minors, they are an important voice to include in the process. They will inherit the river.

Appendix A: 2022 Mississippi River Survey

This below two page survey was administered to participants at the completion of a tour.

2022 Mississippi River Survey   Tour #:

The Army Corps of Engineers has completed their disposition study of Upper St. Anthony Falls. They will begin their study of Lower St. Anthony Falls Lock and Dam and Lock and Dam No. 1 next. This phase will consider dam removal. Your responses will shape future research and advocacy for the river. We will summarize survey results in a report to Minnesota political leaders and the Army Corps. All responses are anonymous.

1. How often do you visit the river?

- ☐ Every day
- ☐ Several times a week
- ☐ Several times a month
- ☐ Several times a year
- ☐ I rarely visit the river
- ☐ I do not live in the area

2. What activities do you regularly participate in at the river?

- ☐ Motorboating
- ☐ Rowing
- ☐ Kayaking, canoeing or paddleboarding
- ☐ Hiking, running, walking
- ☐ Biking
- ☐ Car and motorcycle touring
- ☐ Fishing
- ☐ Grilling, picnicking, celebrating
- ☐ Wildlife viewing
- ☐ Foraging, harvesting, collecting
- ☐ Playground use
- ☐ Other: ____________________

3. Based on your understanding, what is the primary purpose of the locks and dams?

- ☐ Flood control
- ☐ Recreation
- ☐ Water supply
- ☐ Navigation
- ☐ Invasive species control
- ☐ I don't know

4. Did you know about the Army Corps Mississippi disposition studies before today's presentation?

- ☐ Yes
- ☐ No

5. How likely are you to participate in the Army Corps disposition studies on the Mississippi?

- ☐ Very likely
- ☐ Somewhat likely
- ☐ Not likely

6. What type(s) of information would be most useful to you before you participate in an Army Corps disposition study in the future?

- ☐ Current and future costs of maintaining the infrastructure
- ☐ Existing and potential safety hazards associated with the infrastructure
- ☐ Ecological impacts
- ☐ Social and community impacts
- ☐ List of alternatives the Corps is required to consider
- ☐ Other: ____________________

7. What would be the most convenient way for you to share your opinion with the Army Corps in the future?

- ☐ In-person public forum
- ☐ Online public forum
- ☐ Written comment
- ☐ In-person survey
- ☐ Online survey
- ☐ Social media
- ☐ Other: ____________________

The next four questions refer to the future of Lower St. Anthony Falls and Lock and Dam No. 1 (Ford Dam)

8. What role should the Army Corps/federal government play in maintaining and operating the Lower St. Anthony Falls Lock and Dam and Lock and Dam No. 1 (Ford Dam)?

9. How can Mississippi River studies engage those who may have been historically excluded from political and infrastructural decision making?

10. What benefits or drawbacks do you think would result from dam removal in the Mississippi Gorge?

11. What do you wish for the Mississippi River?

Thank you for completing the survey.

C.3.4 North American Native Fish Association

Fritz Rohde President · North American Native Fishes Association
2000 Trinity Avenue · Wilmington · North Carolina · 28411

December 12, 2022

To: District Engineer, U.S. Army Corps of Engineers, St. Paul District,

The North American Native Fishes Association, Inc. (NANFA) is a 501(c)(3) not-for-profit, tax-exempt corporation dedicated to the appreciation, study, and conservation of the continent's native fishes. One of NANFA's objectives is advocating for the protection/restoration of aquatic habitats.

NANFA's position on the US Army Corps of Engineers (USACE) disposition study for Lower St. Anthony Falls and Lock & Dam 1 would be supporting the eventual removal of these structures and restore the river reach which once held miles of rapids through the area known as the Mississippi River Gorge. However, before a decision is made, the following questions should be studied and answered.

- The largest dam removal project in the US on the Klamath River involving four dams in California and Oregon has been approved to begin next year (see: Dam demolitions set for Klamath River in Western U.S. will be biggest in history : NPR). Will the decision process used and studies done be reviewed as a possible guide for the two Mississippi River locks and dams? Many of the questions asked here may apply.
- Has the century of accumulating sediments upstream of the lock and dams been analyzed for contaminants?
- If the results reveal the sediment is not laden with contaminants, what are the impacts to stream morphology and depths downstream in Mississippi River Pool 2?
- Are there recent and thorough fish surveys both upstream and downstream of both locks and dams to assess how many species may re-colonize the impounded reaches? This should be full community studies beyond the standardized surveys targeting large species.
- Currently, the reach above the locks and dams has very limited recreational access. A restored reach could offer many opportunities for angling, birding, canoeing, kayaking, and hiking in a major metropolitan area. A recreational analysis would provide answers to the feasibility of these activities and potential benefits to tourism.
- Both locks and dams generate electricity. Hydropower may be called green energy, but is an inefficient source and the impacts to the stream environments upstream of the

structures are significant. Excel Energy has moved up their timetable to close non-nuclear power plants in Minnesota because wind and solar energy development is rapidly replacing what these plants generate. Maintaining and licensing of the lock and dams would be an ongoing cost. What are the estimated costs of keeping these structures versus removing them? Can the little electricity currently generated be replaced by true green energy?

- Are there government funding sources available to conduct feasibility studies and dam removal? The USACE recently proposed to assist the city of River Falls, Wisconsin where two hydropower dams are slated for removal, but limited funding will delay demolition for decades. USACE has offered substantial cost sharing to conduct studies and removing both structures in a much shorter period (see: Federal funds could quicken Kinnickinnic River dam removal (stcroix360.com).

Please keep NANFA on your contact list for updates on the disposition study and future public comment deadlines.

Sincerely,

Fritz Rohde

President, NANFA

C.3.5 University of Minnesota

UNIVERSITY OF MINNESOTA

Crookston • Duluth • Morris • Rochester • Twin Cities

Office of the Senior Vice President for Finance and Operations

301 Morrill Hall
100 Church Street S.E.
Minneapolis, MN 55455

November 18, 2022 *Sent via e-mail to MplsLocksDisposition@usace.army.mil*

District Engineer, U.S. Army Corps of Engineers St. Paul District
ATTN: Regional Planning and Environment Division North
332 Minnesota St., Suite E1500
St. Paul, MN 55101

To the District Engineer,

The University of Minnesota (the University) appreciates the opportunity to comment on the scope of the Lower St. Anthony Falls and Lock and Dam 1 Disposition Study (the Study). In 2021 the University submitted a letter of comment on the Upper St. Anthony Falls Lock and Dam Disposition Study's Tentatively Selected Plan (TSP), "Alternative 1a, Complete Deauthorization and Disposal combined with a monetary incentive for expediting the disposal." In anticipation that the current Study could result in similar findings, many of the comments below reiterate concerns from the University's previous letter. The University will comment on this Study's TSP as well.

As with the previous study, the University is concerned about potential outcomes, in particular Complete Deauthorization and Disposal, for these primary reasons:

1. potential for transfer of ownership to an entity/organization with unknown qualifications and capacity to operate and maintain the property; and
2. potential adverse effects to University facilities during flood flows due to any changes in lock operations which historically have mitigated flood impacts.

As in 2021, the University requests that if conveyance of the property and facilities is considered, a covenant or similar requirement be included obligating the receiving party or parties not only to continue to operate the locks for flood mitigation purposes, or to otherwise provide mitigation acceptable to affected parties, but also to maintain the properties consistent with Corps standards to ensure long term structural stability and function.

Following is more detail regarding the University's concerns and University facilities that depend on the current river regime in the Study area.

Transfer of Ownership

Consistent with letters of comment on the previous study submitted by the University and other stakeholders in 2018, 2019 and 2021, the University recognizes the Corps as **uniquely qualified to own, maintain and operate** the lock facilities. The University requests that the scope of the Study define potential transfer of ownership of the locks to include the following:

1. a rigorous process to certify that a prospective receiving party is qualified technically and financially to operate and maintain the locks indefinitely;

2. consultation with adjacent property owners including but not limited to the University, Xcel Energy, Minneapolis Park & Recreation Board and the City of Minneapolis; and
3. consideration of the disposition of the Upper St. Anthony Falls Lock and Dam.

Potential Adverse Effects During Flood Flows
Continued competent operation of the locks is essential to managing flood flow and levels in the Intermediate Pool and Pool 1. The St. Anthony Falls Laboratory (SAFL) depends on current elevations and flood mitigation practices in the Intermediate Pool, not only for continuity of operations but for the structural stability of the SAFL facility itself.

Renewable Energy
The scope of the Study should consider the public value of existing and potential hydropower production at both lock facilities. The unused auxiliary lock at Lock and Dam 1 presents unique opportunities for hydropower research and testing, especially given recent interest expressed by the Department of Energy in supporting research in small modular hydropower technologies.

University Facilities
The scope of the Study should consider the potential impacts of disposition on facilities that support the University's statewide mission. The following facilities are adjacent to the Intermediate Pool and Pool 1. As described above, these could be at increased risk of adverse effects during flood flows if flood mitigation functions historically fulfilled by lock operations were to cease.

Saint Anthony Falls Laboratory
SAFL, located at 2 Third Street SE, is an internationally recognized water hydraulics research laboratory located on the northeast bank of the St. Anthony Falls (the Falls) and adjacent to both the Upper Pool and the Intermediate Pool. Research and research training at SAFL are intimately tied to the Mississippi River. Operation of Lower St. Anthony Falls (LSAF) is essential to maintaining water levels in the Intermediate Pool, which receives the outflow of river water from SAFL. An increase in the intermediate pool elevation due to changes at either the upper or the lower lock and dam could divert additional backwater into SAFL, which would damage research facilities and reduce research space without modifications. A decrease in the pool elevation or fluctuating uncontrolled levels could negatively affect structural stability of riverbank slopes, structure foundations and tunnels, and could change groundwater flows, all of which would raise structural and security concerns due to possible uncontrolled access via the current pool bottom.

The University requests that the scope of the Study consider how changes in ownership, operation, or physical infrastructure at LSAF would affect longstanding water control patterns tied to existing infrastructure, notably: (a) water level control in the Intermediate Pool during normal flow and flooding, specifically investigating surface water effects on buildings, infrastructure, and river bank stability; (b) groundwater flow through, under, or around the St. Anthony Falls area, with emphasis on possible destabilizing effects to existing foundations and tunnels; and, (c) access to the river bed or banks, with respect to security of facilities and public safety.

Acknowledging that disposition of USAF is the subject of the previous study, the University suggests that the scope of the current Study should consider potential effects of disposition on USAF, e.g. loss of tailwater for energy dissipation below the USAF spillway, and vice-versa where USAF disposition options affect LSAF and the intermediate pool.

Irene Claudia Kroll Boathouse

The Kroll Boathouse located at 550 East River Parkway, in East River Flats Park, is the only river access point for rowing programs sponsored by the University's Intercollegiate Athletics and Recreation and Wellness departments. Rowing at the University has been a NCAA Division 1 Women's Varsity sport since 2000 and a student club sport since 1957. Pool 1 provides ideal practice and competition conditions for the Women's Varsity and Men's Club Rowing teams. From February through November, over 150 athletes use the river Monday through Saturday. For such uses it is critical that flows in Pool 1 are kept within a safe range below 30,000 cfs, and that water surface elevations are maintained to support water access from existing piers.

Native Canoe Program

Adjacent to the Boathouse, the Native Canoe Program operated by the University's Department of American Indian Studies' uses traditional Indigenous watercraft and Indigenous water-based ecological knowledge and technology to advance community-engaged research, teaching, and service. The Program also engages K-12 youth groups with experiential learning and teaching. The controlled water elevations and flows in Pool 1 are important to the program maintaining this access to the river.

Elmer L. Andersen Library Caverns

The University's Elmer L. Andersen Library at 222 21st Avenue South includes archival storage caverns that provide environmentally controlled storage for many rare and irreplaceable books, manuscripts, artifacts and map collections. The caverns are accessed via West River Parkway and were designed to avoid flooding during a 500-year flood; a groundwater drain and pump system installed around the perimeter prevents flooding from groundwater flow based on the river's conditions. Changes to flood levels in Pool 1 could increase risk of damage to collections due to water infiltration into the caverns.

District energy, steam heat and storm sewer outfalls

The University operates two energy plants within the Study area. The Southeast Steam Plant at 600 Main Street SE is adjacent to the Intermediate Pool; the Main Energy Plant at 1180 Main Street SE is adjacent to Pool 1. A network of sandstone tunnels dating back to the early 1900s hosts steam distribution piping serving University buildings on both sides of the Mississippi River, providing both heat and process steam critical to campus operations. Water level increases resulting from operational changes at the locks could cause river water and/or groundwater to enter these tunnels.

The University owns several storm sewer outfalls in Pool 1. Changes to flood levels or flows in Pool 1 could impact the structural stability and function of this critical infrastructure. Consistent pool elevations also provide waterway access to critical tunnel and sewer infrastructure for maintenance and repairs.

In conclusion, these comments are intended to highlight information particularly relevant to the Study. Through its multidisciplinary teaching, research and outreach the University is already a contributor to both the natural, human and recreational environments about which the Study seeks feedback. The University welcomes continued engagement and appreciates the opportunity to present its concerns regarding the potential impacts of disposition on its mission, activities and infrastructure.

Sincerely,

Myron Frans
Senior Vice President for Finance and Operations

Matt Kramer
Vice President of University Relations
Interim Vice President for University Services

C.4 Hydropower

C.4.1 Brookfield Renewable

Brookfield
Renewable U.S.

December 16, 2022

Patrick Storms
Director of Operations
Brookfield Renewables U.S
800 Starbuck Avenue, Suite 802
Watertown, NY, 13601

To whom it may concern,

Brookfield Renewable U.S. continues to build on a history of delivering the most reliable green energy to communities of Minneapolis-St. Paul and beyond. Holding licenses, as authorized by the Federal Power Act, for the Twin Cities (expires 2034) and Lower Saint Anthony Falls (expiries 2056) projects will enable Brookfield to continue to prioritize providing power to the region for decades to come.

The Twin Cities Hydro-electric project is located on the Mississippi River in the city of St. Paul, Minnesota. The hydro station is situated on the St. Paul side of the river, at the eastern end of the U.S. Army Corps of Engineers Lock and Dam No. 1. The lock and dam were constructed in 1917, which was built in anticipation of environmentally sustainable hydropower, and later rebuilt in 1929 expanding from one lock to two locks in 1932. The dam structure is a unique design, which utilizes concrete panels, precast in the lock structure, as a dam facing. The Twin Cities Powerhouse and generating units were constructed by the Ford Motor Company in 1924 to provide power to the Ford Motor Company's Twin Cities Assembly Plant. The hydro station consists of four vertical turbine-generating units with a total installed capacity of 17.92 megawatts (MW's) and a total discharge flow of 7,000 CFS. Upon initial construction and operation, Ford Motor Company was granted a fifty-year operating license through FERC expiring in 1973. The project was then relicensed in 1974 and 2004 each for an additional 30 years expiring in 2034. In April 2008, Brookfield Renewable Power Inc. acquired the facility and has continued to invest in the perpetual asset providing clean, renewable energy to the Midwestern wholesale electricity market. At the time of the sale, Brookfield Renewable Power assumed the existing 30-year FERC license for the facility. Congruent with other FERC projects Brookfield Renewable Power operates, it is the current intent that the Twin Cities Hydro-electric project will undergo the FERC relicensing process to extend the life of this facility an additional 30-years operating under the existing agreement with the USACE.

The Lower Saint Anthony Falls Hydroelectric project is located on the Mississippi River in the city of Minneapolis, Minnesota at the U.S. Army Corps of Engineer's Lower Saint Anthony Falls Lock and Dam. In 1937, Congress authorized the Minneapolis Upper Harbor Project constructing two locks to lift vessels over Saint Anthony Falls, constructing Lower St. Anthony Falls which was completed in 1956 and the upper lock in 1963. The construction of the Lower St. Anthony Falls Lock and Dam included two lock channels to allow for safe, reliable, and environmentally sustainable waterborne transportation on the Upper Mississippi River for the movement of commercial goods. In 2006, FERC issued a fifty-year license to SAF Hydro LLC, a subsidiary of Brookfield Renewable Power, to construct and operate a hydroelectric facility located in the auxiliary lock. SAF hydro's ownership includes two Minneapolis based development companies. SAF Hydro and the

U.S. Army Corps of Engineer's signed a memorandum of agreement for access, design, and construction in 2006. The USACE accepted the proposed design for the facility in 2009, construction of the facility began in April 2009 and the facility was later placed into operation in 2011. The project represented an investment of $35 million in clean energy for Minnesota. Funding for the project was provided by customers of Xcel Energy through a grant from the Renewable Development Fund, the Project also qualifies for clean energy tax credits from the American Recovery and Reinvestment Act. The hydro station consists of sixteen individual turbines installed in eight modules with a total installed capacity of 10.32 megawatts (MW's). Brookfield continues to operate and maintain the facility with an experienced operations team in conjunction with the Twin Cities Hydroelectric facility continually investing in the perpetual asset providing, clean, renewable energy to the Midwestern wholesale electricity market.

Understanding the statutory obligation of the United States Army Corps of Engineers (Water Resources Government Act of 2014) to review the value of their investments, Brookfield would like to provide input to be included for matters of assessment.

Goals set at the federal and state levels to meet renewable energy goals include hydroelectric along with wind and solar as a desired methods of power production, exemplifying identified standards associated with reducing carbon emissions. President Biden has set a target for the United States to achieve a 50-52 percent reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030. In pursuit of that, the Administration has set a goal to reach 100 percent carbon pollution-free electricity by 2035. Removal of the hydropower capacity at Lower St. Anthony Falls and Lock and Dam 1 would be step away from achieving those stated goals.

Currently, the Twin Cities and Lower Saint Anthony Falls projects produce 104.3 GWh's and 62.8 GWh's of clean energy respectively or enough to power 25,000 homes over the course of a year. Removal of Lock & Dam 1 would cause substantial changes to water levels and usher in new conditions that would ultimately render Brookfield's facilities inert. The loss of these dams as a viable energy source would necessitate an immediate equal or greater replacement to the grid. Replacement with another renewable option would be less efficient and more costly than what is provided for under the current circumstances. In addition to these impacts, the removal of Lock & Dam 1 would impact the Meeker Island lock and dam which is currently submerged in Pool 1. This structure, which is listed on the National Register of Historic places, is a historically significant structure in the history of the Twin Cities. Creating a free-flowing river in Pool 1 would require the removal of an 8-foot-high segment of this dam. Additional information on the historical significance of both the Meeker Island structures and Lock & Dam 1 can be found in the publication entitled *"The Secret History of the Mississippi River Earliest Locks and Dams"* by John O. Anfinson, District Historian for the St. Paul District.

Hydropower is one of the most highly regulated industries in the nation. Based on Federal Energy Regulatory Commission licensure and compliance standards, private companies like Brookfield work interdependently with government agencies to ensure the reliability of one of the most fundamental requirements of society. This model of a successful public-private partnership would certainly be undermined if the USACE were to make radical changes to the fundamental conditions of power production or oversee the transfer of property/infrastructure to an entity that would alter river conditions that what was considered perpetual when Brookfield was granted licensure by the FERC.

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Brookfield is proud to be a tax paying corporate citizen that invests millions of dollars within host communities like Minneapolis- St. Paul, creating jobs, providing numerous recreational opportunities and being active environmental stewards. Under the current arrangement benefits accrued to the citizenry of Minnesota are clear and quantifiable. It is the position of leadership that it would benefit all concerned parties to stay the course and allow for the growing demand for renewable energy continue being met. Furthermore, it would be helpful to address the misalignment of USACE's primary charter which currently does not include the maintenance of renewable energy and that of the FERC which prioritizes grid reliability fortified by renewables.

USACE recently invested $4.5 million to upgrade the infrastructure at Upper Saint Anthony Falls on behalf of the American taxpayers, its removal would be an additional layer of fiscal imprudence ultimately compounding the lasting negative economic impacts of the loss of renewable energy being produced at these locations. The removal of Upper Saint Anthony Falls would be an abrupt change of course that along with the stated harmful economic impacts would jeopardize the stability of the Stone Arch Bridge and I-35W, Saint Anthony Falls Bridge, allow for more garbage to be flushed through the river and impede the recreation of residents and tourists alike.

Brookfield appreciates the opportunity to provide commentary and stands ready to explain in further detail if it would please the United States Army Corps of Engineers.

Regards,

Patrick Storms

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C.5 American Rivers, Friends of the Mississippi River, National Parks Conservation Association

Disposition Study for Lower St. Anthony Falls Lock and Dam and Lock and Dam No. 1

District Engineer, U.S. Army Corps of Engineers, St. Paul District

ATTN: Regional Planning and Environment Division North

332 Minnesota St., Suite E1500

St. Paul, MN 55101

Submitted via email to MplsLocksDisposition@usace.army.mil

December 18, 2022

Scoping Technical Comments from:

American Rivers

Friends of the Mississippi River

National Parks Conservation Association

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2 GENERAL COMMENTS

For the first time in over a century, we have an opportunity to reimagine the future of the Mississippi River and the Twin Cities' national park, the Mississippi National River and Recreation Area. The U.S. Army Corps of Engineers' (Corps) disposition study for the Lower St. Anthony Falls Lock and Dam (LSAF) and Lock and Dam 1 (LD1) is a critical step toward determining what the next century will bring. Will these structures remain in place or be removed and a free-flowing river restored?

To answer that question, it is imperative that we have all available information so that we can determine the best outcome for our communities, the river, and the national park. Our comments outline the many areas of concern that the Corps needs to address in the study. We are especially concerned about the structural integrity of LD1, which was categorized under the Dam Safety Action Classification as "2 – High Urgency of Action" due to an elevated risk of failure caused by erosion that would be virtually impossible to detect with sufficient notice for intervention. However, the dam was subsequently reclassified to "4 – Low Urgency of Action" not because the erosion and structural integrity issues were resolved, but because failure of LD1 would likely not cause loss of life and economic consequences are low to moderate.

The structural integrity of LD1 has profound implications for any future owner and suitability of the structure for alternative uses. Given this information, the Corps needs to provide additional details about the risk of dam failure within the 50-year planning period and explain how dam failure would impact recreational use of the reservoir.

The Conservation Organizations also recommend the Corps:

1. Fully account for all costs and benefits of the alternatives, including costs and benefits associated with ecosystem services;
2. Conduct an Environmental Impact Statement instead of an Environmental Assessment;
3. Comply with the Water Resources Development Act, Clean Water Act, Endangered Species Act, and National Historic Preservation Act; and
4. Conduct consultation with the National Park Service, U.S. Fish and Wildlife Service and Dakota and Ojibwe Tribal Nations.

We also urge the Corps to adhere to documented best practices for future public engagement on the disposition study. Dr. Roopali Phadke at Macalester College has documented community engagement needs and recommendations specific to this disposition study in the report "Engagement Matters: Public Understandings of River Infrastructure" (attached hereto as Appendix A).

The geographic scope of the Disposition Study includes a roughly 8-mile stretch of river below St. Anthony Falls to the confluence of the Minnesota River. This river stretch is formally known as "the Gorge" and is currently impounded by Lock and Dam 1 and Lower St. Anthony Falls Lock and Dam. Throughout these comments, the term "Gorge" refers to the area that encompasses both dams and their impoundments.

These technical comments are submitted on behalf of three organizations (collectively referred to hereafter as "the Conservation Organizations"):

National Parks Conservation Association (NPCA) is the independent, nonpartisan voice working to strengthen and protect America's national parks. Founded in 1919, NPCA works with its 1.6 million members and supporters nationwide, including over 27,000 in Minnesota, to protect and preserve our nation's natural, cultural, and historic heritage for present and future generations. NPCA is headquartered in Washington, D.C. and has 27 local and regional offices across the country, including a field office in Minnesota.

American Rivers protects wild rivers, restores damaged rivers, and conserves clean water for people and nature. Since 1973, American Rivers has protected and restored more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects, and an annual America's Most Endangered Rivers® campaign. Headquartered in Washington, DC, American Rivers has offices across the country and more than 275,000 members, supporters, and volunteers. The Upper Mississippi River is one of 11 priority river basins where American Rivers concentrates the bulk of its activities. In the basin, we are working to reform the management of the Mississippi River and reconnect rivers to their floodplains.

Friends of the Mississippi River (FMR) was established in 1993 to be the citizen, community, and environmental voice for the river in the Twin Cities region. Over nearly 30 years, FMR has grown to 16 board members, a 12-member council of advisors, 23 staff, 2,500 members, and over 6,000 annual volunteers, event participants, members, and advocates. FMR's focus areas include policy and advocacy on issues affecting the health of the Mississippi River and riverfront communities, habitat preservation and restoration, and stewardship and education.

3 Technical Comments

3.1 Disposition Study Implementation Guidance

Two guidance documents exist for the Corps' disposition study process:

1. 2016-08-22. Dalton, James C. Interim Guidance on the Conduct of Disposition Studies.
2. 2019-04-25. Dalton, James C. Revised Implementation Guidance for Section 1168 of the Water Resources Development Act (WRDA) of 2018, Disposition of Projects.

These two memos provide an extensive list of questions that the Corps must answer when considering disposition of completed projects. As such, the Conservation Organizations provide the following resources, questions, and recommendations in considering the requisite questions.

3.1.1 Benefits and Costs of Disposal/Retention

According to the 2016 Dalton Memo:

> The study's focus is on whether federal interest exists to retain the project for its authorized purpose(s), based on an evaluation and comparison of the benefits, costs, and impacts (positive and negative) of continued operation, maintenance, repair, replacement, and rehabilitation, or the lack thereof, on the one hand and

of deauthorization and disposal of the associated real property and Government-owned improvements on the other.[1]

As part of this assessment, the Corps must not only review monetary benefits and costs but conduct a "public interest review" that "reflects the national concerns for both the protection and utilization of important resources" as outlined in the Corps General Regulatory Policies.[2]

The Conservation Organizations suggest the Corps incorporate the following impacts, costs, and benefits into their considerations.

3.1.1.1 Retention of LSAF and LD1, Corps maintains ownership

3.1.1.1.1 Benefits/Positive Impacts

1. **Recreation benefits.**

There are many active recreational users who use the reservoirs behind Lock and Dam 1 and Lower St. Anthony Falls. These users include boaters, rowers, fishers, and other recreationalists. The Corps should make use of recent studies of visitor demand in their analysis, such as what was used in the Mississippi Gorge Regional Park Master Plan.[3]

2. **Hydropower benefits.**

The Corps should include an analysis of the carbon emission reductions generated by the hydro-kinetic facilities operating at these sites. This analysis should be limited to the actual power produced, instead of the power generating capacity (see attached Appendices B and C). Actual production is significantly lower than capacity, as shown by recent filings with the Federal Energy Regulatory Commission. In addition, the Corps must also calculate the emissions in the context of the modified stream. Studies indicate that reservoirs release a substantial amount of methane due to the decomposition of organic matter and other factors, while free-flowing rivers capture carbon. Peer-reviewed models are available that the Corps should use to provide a clear analysis of hydropower benefits.[4]

3.1.1.1.2 Costs/Negative Impacts

1. **Operation and maintenance of the lock and dams.**

The Corps should provide an accurate accounting of operation, maintenance, rehabilitation, and deferred maintenance expanses of the locks and dams. This should include the following items:

- All operation, maintenance, and rehabilitation expenses for the past 50 years, broken out by fiscal year.

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[1] 2016-08-22. Dalton, James C. Interim Guidance on the Conduct of Disposition Studies. https://planning.erdc.dren.mil/toolbox/library/MemosandLetters/2016_Disposition_Memo.pdf
[2] 33 CFR 320
[3] Minneapolis Park & Recreation Board. 2019. Mississippi Gorge Regional Park Master Plan. Available at https://www.minneapolisparks.org/park-care-improvements/park-projects/current_projects/mississippi_gorge_regional_park_master_plan/
[4] See Prairie YT, Alm J, Harby A, Mercier-Blais S, Nahas R. 2017. The GHG Reservoir Tool (G- res), UNESCO/IHA research project on the GHG status of freshwater reservoirs. Available at www.hydropower.org/gres

- Date of last major rehabilitation with an itemized list of work completed and costs of those separable elements.
- List of deferred maintenance and estimated costs.
- Anticipated major rehabilitation needs within the next 50 years.
- Additional costs associated with the structures, such as dredging, dam safety, inspections, gas and electric bills, security, fencing, building maintenance, etc.

2. Carbon emissions from the reservoirs due to impoundment.

As mentioned in above, to provide a clear understanding of the carbon emissions saved (or lost) due to impoundment and the generation of hydropower, the Corps must calculate the carbon emissions from the reservoir itself.

3. Mitigation of the persistent impacts of impoundment.

The Corps must incorporate into the costs of retaining the dams, the cost of mitigating the environmental impacts of the dams, as discussed in elsewhere herein.

4. Accounting of ecosystem services gains/lost since impoundment and 50 years into the future.

The Corps must calculate the ecosystem services lost and gained by converting the riffle-pool rapids habitat of the Gorge to flat-water reservoirs. This calculation must look back to when the dams were constructed and track how the ecosystem services have been impacted by impoundment, compared to the historic ecosystem-type that would have existed had the dams never been built and would be restored if the dams were removed. This accounting must be incorporated into the monetary costs and benefits and is discussed more elsewhere herein.

5. Costs to address scour issues at locks and dams.

The "Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1, Section 216 Disposition Study, Decision Meeting Briefing Report," (hereafter "Decision Meeting Briefing Report), also noted a scour and stability issue at LD1 that lowered its Dam Safety Action Classification to DSAC 2 (High Urgency) but was reclassified after further analysis showed "low likelihood of life loss" if the dam failed. [5] fully disclose any and all history associated with dam stability and scouring. The Corps must provide, in their history of costs, any work completed to address scour and stability issues. If there are projected costs associated with scour and stability at the dam, the Corps must include that in their cost analysis.

The scour and stability issue should raise *significant* concerns for taxpayers and potential future owners. How likely is it that the dam will fail within the next 50 years if the scour and stability issues go unresolved? The Corps needs to address this in the disposition study, especially in the context of climate change, which is increasing average discharges and timing of higher

[5] USACE. 2017-08-16. Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1, Minneapolis, MN, Section 216 Disposition Study, Decision Meeting Briefing Report at 8.

discharges (more water over longer periods of time) in the Mississippi River.[6] Such increases in river discharge will put more pressure on the dam and could accelerate potential failure.

6. **Potential reduction in quality of and public oversight over property maintenance and conditions.**

The Conservation Organizations are extremely concerned about the potential for the property to deteriorate, creating unsightly or dangerous conditions. A 2013 report found that "[f]unding streams in the U.S. federal budget over the past 20 years consistently have been inadequate to maintain all of [the Corps] infrastructure at acceptable levels of performance and efficiency."[7] While recent federal investment packages (the Inflation Reduction Act and Infrastructure Investment and Jobs Act) have provided a temporary boost to the Corps budget, it will not be lasting. The fact remains that the nation's water infrastructure is "built-out," meaning there is more water infrastructure in the U.S. than the nation needs and has the capacity to maintain.[8] And, inland waterway users – the primary beneficiaries of the inland navigation infrastructure – recently succeeded in reducing the private cost-share obligations for the inland waterways.[9] Additionally, the Infrastructure Investment and Jobs Act provided new construction funding to add even more infrastructure to the Mississippi River inland navigation system,[10] which will further strain the operations and maintenance budget of the Mississippi Valley Division.

With ever more limited resources for operating and maintaining infrastructure actually in use, it is fathomable that the Corps will allow these unused structures to fall into disrepair. The Corps needs to provide an analysis of the realistic funding constraints for operating and maintaining unused infrastructure as part of the Disposition Study.

This analysis should include the cost of securing and maintaining unstaffed or lightly-staffed properties (including the cost of ongoing security personnel) to ensure that unauthorized entry, vandalism, etc. do not lead to safety hazards, deterioration in the condition of Corps properties, deterioration in the condition and value of neighboring properties, unsightly conditions for visitors of neighboring tourist attractions and parks, etc.

3.1.1.2 Disposal of LSAF and LD1, keeping structures in place

It is difficult to understand what public interest benefits would accrue from this alternative without knowing how and for what purpose the dams and other associated infrastructure would be used. There is also a nearly infinite array of potential alternatives for partial disposal of the infrastructure. The Conservation Organizations provide the following general comments on the benefits and costs of a disposal alternative that would retain most or all of the infrastructure and look forward to responding in more depth when the Corps publishes the Draft Disposition Study.

[6] Houser, J.N., ed. 2022 Ecological Status and Trends of the Upper Mississippi and Illinois Rivers: U.S. Geological Survey Open-File Report 2022-1039, 199 p., https://doi.org/10.3133.ofr20221039.
[7] National Research Council. 2013. Corps of Engineers Water Resources Infrastructure: Deterioration, Investment, or Divestment? The National Academies Press. Washington, D.C.
[8] Id.
[9] Section 108 of the Water Resources Development Act of 2020.
[10] In reference to the recent Congressional funding via the Infrastructure Investment and Jobs Act of a new lock at LD25 and funding for the Navigation and Ecosystem Sustainability Program.

3.1.1.2.1 Benefits/Positive Impacts

1. **Reduction in Corps maintenance and operations costs.**

Regardless of the fate of the infrastructure, the primary benefit of this alternative would be a cost-savings for the Corps as they would no longer be responsible for operations and maintenance expenses.

3.1.1.2.2 Costs/Negative Impacts

1. **Liability and insurance costs for private ownership.**

The Corps must make clear that if dams are transferred to another owner, jurisdiction over dam safety would be transferred to the Dam Safety Program within the Minnesota Department of Natural Resources, unless the dam owner and hydropower operator are the same entity, in which case dam safety jurisdiction would transfer to the Federal Energy Regulatory Commission. In either scenario, the dam owner is liable for public safety at the dams, including infrastructure maintenance, site security, dam failure risk, and risks of injury to people on the facilities. According to data from Stanford University's National Performance of Dams Program,[11] 24 dams have failed per year on average since 1980. In addition, dams can be attractive nuisances - Brigham Young University maintains a database[12] that currently includes 625 drownings in the hydraulics downstream of dams around the United States. Insurance costs for private dam ownership are high due to uncertainty around liability risk and costs of dam ownership.

2. **Loss of public commercial and recreational motorized boat access in the reservoirs, should a new owner cease or reduce lockage at LD1 and/or LSAF.**

A private owner would have the discretion to completely close public access through the locks, eliminating some types of recreational boating as well as routes commonly used by commercial tour operators (Padelford Riverboats, Magnolia Blossom, Minneapolis Queen, Paddle Bridge Guide Collective). Additionally, if the Corps easements and riverside property were transferred to a private owner, riverfront access points for fishing and boating could also be restricted.

3. **Potential reduction in quality of and public oversight over property maintenance and conditions.**

As mentioned above, the Conservation Organizations are concerned that the Corps lacks the resources to prevent deterioration of the infrastructure. Likewise, the Conservation Organizations are concerned that any other federal, state, local or private entity would not have the resources necessary to keep up the requisite maintenance. The Conservation Organizations remind the Corps that the structures are located within a major metropolitan area and is surrounded by public parkland with high visitor use. Any alternative that could lead to

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[11] National Performance of Dams Program. 2018. *Dam Failures in the U.S.* Stanford University NPDP-01 V1.

[12] Brigham Young University; Locations of Fatalities at Submerged Hydraulic Jumps; https://krcproject.groups.et.byu.net/browse.php; accessed December 16, 2022.

abandonment of the structures and subsequent dereliction is unacceptable from a public interest perspective.

3.1.1.3 Disposal of LSAF and LD1, removing structures for environmental benefits

In 2018, Congress ordered the Corps to also consider removal of the project for environmental benefits.[13] To meet this legislative requirement, the Corps must estimate the cost of removal and compare it to the cost of continued operations and maintenance over a 50-year planning period. In addition to considering anticipated operation and maintenance, to accurately estimate project costs, the Corps must consider the full range of benefits associated with dam removal, which can be substantial. The Conservation Organizations encourage the Corps to consider the multiple studies regarding the economic benefits of dam removal provided in Appendices D-G.

3.1.1.3.1 Benefits/Positive Impacts

1. **Changes in recreational opportunities**

At the moment, recreational opportunities on the impounded Mississippi River are limited. Recreational opportunities are primarily motor boating, paddling, rowing, and bank fishing. Dam removal would change recreational opportunities in the river and allow for more diverse uses, including increased paddling, whitewater kayaking, inter-tubing, wading, fly fishing, and bank fishing. The increase in the diversity of users and access to more types of recreation on the river can lead to tremendous economic benefits. A study of the Kennebec River in Maine found that removing the Edwards dam generated $2.5-$38.2 million for improved recreational fishing quality and $297,000 - $2.7 million for improved river recreation quality.[14]

2. **Protection and restoration of a Special Aquatic Site, pursuant to the Clean Water Act.**

The Mississippi River Gorge meets the definition of a "Special Aquatic Site," and as such, the Corps must consider that the degradation of the Gorge's riffle-pool ecosystem "may represent an irreversible loss of valuable aquatic resources."[15] As such, the Corps must consider their obligations to protect and restore the Gorge as required by the Clean Water Act. If the impacts of continuing to impound the Mississippi River Gorge cannot be mitigated, the Corps must find in favor of removing the dams to meet their Clean Water Act obligations.

3. **Ecosystem services gained by converting the reservoirs to a riffle-pool complex.**

The Corps must complete an examination of the ecosystem services tradeoffs between impoundment and dam removal and restoration. Numerous studies exist on how to calculate

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[13] 2019-04-25. Dalton, James C. Revised Implementation Guidance for Section 1168 of the Water Resources Development Act (WRDA) of 2018, Disposition of Projects. https://www.mvp.usace.army.mil/Portals/57/docs/Civil%20Works/Projects/MplsLocksDisposition/WRDA2018_Sec1168_Disposition_of_projects.pdf?ver=2019-08-20-110847-820

[14] Boyle KJ, Teisel MF, Moring JR, Reiling SD. 1991. Economic benefits accruing to sport fisheries on the Lower Kennebec River from the provision of fish passage at Edwards Dam or from the removal of Edwards Dam. Chelsea (ME): Maine Department of Marine Resources.

[15] 40 CFR 230.1(d)

the services nature provides. This is discussed in more detail under elsewhere herein and examples are provided in Appendix H.

4. **End of ongoing structure maintenance, operation, rehabilitation, and associated costs.**

As discussed elsewhere, any disposal scenario would greatly reduce and/or eliminate the Corps obligations to operate, maintain, and rehabilitate the infrastructure and other costs associated with the site. The Corps must provide a complete accounting of these expenses.

5. **Potential expansion of public parkland on exposed shoreline.**

Removal of the dams would lower water levels in the Gorge. This would expose more acres of shoreline, floodplain, and islands within the Mississippi Gorge Regional Park and Mississippi National River and Recreation Area. Critical questions about ownership, rights of way, easements, and other land/deed restrictions must be resolved should the dams be removed, but it is likely these new land formations and areas will increase the useable space for visitors and recreational users and should be considered a public benefit.

3.1.1.3.2 Costs/Negative Impacts

1. **Cost of removal and ecosystem restoration.**

Dam removal and ecosystem restoration of the Gorge will be expensive. The Corps should consult with the U.S. Fish and Wildlife Service National Fish Passage Program, the NOAA Restoration Center, academic institutions, and experienced dam removal consulting firms to estimate the cost of dam removal and associated restoration. American Rivers has competitively pre-qualified a list of experienced dam removal firms that can be furnished upon request.

2. **Sediment management.**

There is a substantial amount of sediment accumulated behind LD1 and LSAF. And, due to the industrial history of the Twin Cities riverfront, there is an elevated risk that the sediment is contaminated with heavy metals and other toxic substances. The Corps needs to conduct an analysis of the sediments and develop a sediment transport model to understand how and where the sediment will move downstream under the dam removal scenario. The Corps should also include a cost analysis of sediment removal should it prove unviable to release all impounded sediment downstream. The Conservation Organizations understand that the Corps has conducted some sediment analysis as part of their dredging operations. Those results should be published as soon as possible to inform the public debate about the future of the Mississippi River in the Twin Cities.

3. **Changes in recreational opportunities (loss of rowing and power boats)**

As discussed in elsewhere herein, changes in recreation may have positive impacts and economic benefits. However, those changes may come at a cost as the existing recreational opportunities for rowing, power boats, and commercial passenger river cruise operators will no longer be available. These changes need to be fully explained and balanced in the analysis. This analysis should include discussion of costs to relocate existing rowing club facilities in the Gorge

(Minneapolis Rowing Club, University of Minnesota), as well as an analysis of potential economically beneficial reuse opportunities for these facilities.

4. **Potential need to mitigate conditions at Ford Area C hazardous waste dump site.**

The Corps needs to analyze how dam removal may change water levels and discharge around the Ford Area C hazardous waste dump adjacent to Lock and Dam 1. If the hydraulic changes impact the stability of the dump, costs associated with cleanup need to be incorporated into the analysis. (At this time, Ford Motor Company owns this site and may be responsible for cleanup costs; the Corps should not assume that cleanup costs will be borne by the public.)

5. **Changes in conditions to and accessibility of the Meeker Island Lock and Dam.**

The Conservation Organizations have several questions about the future of the Meeker Island Lock and Dam that may impact the cost of the dam removal alternative. These questions include: Who owns the structures and are they included in the Disposition Study? How will the structures be impacted by dam removal and is there a need to also remove or modify the structures under the dam removal alternative? Like our concerns expressed elsewhere herein derelict navigation infrastructure (which would be more exposed under a dam removal alternative) poses serious public safety risks and reduces the quality and aesthetic of the Mississippi Gorge Regional Park.

6. **Costs associated with the potential need to modify critical infrastructure.**

There is a substantial amount of critical infrastructure in and around the Gorge. This includes, but is not limited to:

- Stormwater infrastructure, including all outfalls
- Bridges:
    - Ford Parkway
    - Lake Street/Marshall Avenue
    - Canadian Pacific Railway Short Line Bridge
    - East Franklin Avenue
    - Interstate Highway 94
    - Washington Avenue
    - Northern Pacific Railway Bridge #9
    - 10th Avenue
    - Interstate Highway 35W
    - Stone Arch Bridge
- Other infrastructure:
    - Retaining walls (Bohemian Flats and other locations)
    - Upper Saint Anthony Falls Raceways
    - Southeast Steam Plant
    - Hennepin Island slopes
    - Upper St. Anthony Falls Lock and Dam
    - Mill Ruins Park

- University of Minnesota structures
- Utilities

The Corps needs to work with the municipalities, Hennepin and Ramsey counties, the Minnesota Department of Transportation, the University of Minnesota, and other property owners to understand the potential need to modify these structures and estimate those costs under the dam removal scenario. Impacts to boat access for infrastructure inspection and maintenance should also be considered.

7. Loss of hydropower generation.

This cost should be balanced with the cost of replacing hydropower with other renewable energy. This assessment should be based on the average amount of power currently produced, which is substantially lower than the maximum amount of power production authorized.

The replacement cost should also incorporate anticipated changes in the cost of renewable energy sources, such as wind and solar, in the coming 5-15 years. Because any study alternative that includes the end of hydropower production would take many years to implement, replacement power would not be needed immediately. The cost of renewable energy development is likely to drop during this time due to advances in technology as well as subsidies and legislation (including the Inflation Reduction Act) that reduce the cost to renewable energy producers.

According to a 2022 peer-reviewed analysis from the U.S. Department of Energy: "By 2035, solar could cost as little as $22 per megawatt-hour on average. That's down from a 2020 average of $34 per MWh. Wind, for its part, could hit $24 per MWh, down from $32 per MWh two years ago."[16] This anticipated 25-35 percent drop in wind and solar costs is a substantial factor in considering hydropower replacement. The Corps should incorporate this and other federal research into its analysis.

In 2021, the hydropower plants at Lower St. Anthony Falls Lock and Dam and Lock and Dam 1 produced a combined total of 121,978 MWh of power. Using the 2020 average price of solar power, replacing the hydropower produced with solar would cost $4.1 million. Based on Department of Energy projections, that same solar replacement cost would drop to $2.7 million by 2035.

As mentioned above, analysis of hydropower generation costs should also incorporate the impacts of methane emissions caused by the dams, and the benefits of restoring a free-flowing river.

3.1.2 Request for Release of Additional Information Regarding the Federal Interest Determination

According to the 2016 Dalton Memo:

> The district will hold a vertical team decision meeting as soon as possible after, but in all cases within 60 days of the initial receipt of funding or issuances of this guidance, whichever is later. […] The purpose of the Decision Meeting is to

[16] https://www.eenews.net/articles/doe-heres-where-renewable-costs-are-heading/

> establish that Federal interest in the project no longer exists, the project remains a candidate for a disposition study; document and gain vertical concurrence on the scope proceeding to the Tentatively Selected Plan.

Several documents were produced as part of these planning meetings, including the 2017 Decision Meeting Briefing Report. The Conservation Organizations note disappointment that these critically important decision documents have not been released publicly and were only provided when requested under the Freedom of Information Act.[17] To ensure this important document is on the record and available for public review, the Conservation Organizations attached it here as Appendix I. Notably, the 2017 Decision Meeting Briefing Report found that a "Federal interest in the project no longer exists," and the Corps should proceed with the Disposition Study.[18] The Conservation Organizations request the Corps promptly post for the public to review all reports and documents prepared as part of the Decision Meeting about whether a federal interest in LSAF and LD1 still exists.

3.1.3 Comments on Federal Interest Determination "Focused Questions"

As part of the Decision Meeting Briefing Report, the Corps included "1st Iteration" answers to a series of questions required by the 2016 Disposition Study Guidance.[19] In response, the Conservation Organizations share our additional thoughts and comments for the Corps' consideration.

3.1.3.1 An explanation of how the project became a candidate for a disposition study

In the Decision Meeting Briefing Report, the Corps explains that "Section 2010 of the Water Resources Reform and Development Act of 2014 (WRRDA 2014), dated 10 June 2014, directed the Upper St. Anthony Falls (USAF) lock and dam, located at Upper Mississippi River mile 853.9 in Minneapolis, Minnesota, be closed within one year of the date of enactment of the Act." (Executive Summary). Consequently, the upper lock closed to navigation on June 9, 2015.[20]

In the Problem Statement of the "Decision Meeting Briefing Report," the Corps states that:

> USAF, LSAF, and L/D 1 operate as a system providing commercial navigation to the city of Minneapolis. Since the 2015 closure of USAF, commercial navigation has not been able to access the port of Minneapolis. USAF is no longer used for navigation in any capacity; LSAF and L/D 1 have very limited use and the

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[17] On July 27, 2018, NPCA submitted a Freedom of Information Act request to the Corps that requested "any and all documents related to the 'Decision Meeting' conducted by the Corps pursuant to the 'Interim Guidance on the Conduct of Disposition Studies' (CECW-P, 22 August 2016)" specifically as it related to "determinations about whether a federal interest in [USAF, LSAF and LD1] still exists and if it should proceed with a disposition study."

[18] USACE. August 16, 2017. Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1, Section 216 Disposition Study, Decision Meeting Briefing Report.

[19] 2016-08-22. Dalton, James C. Interim Guidance on the Conduct of Disposition Studies. https://planning.erdc.dren.mil/toolbox/library/MemosandLetters/2016_Disposition_Memo.pdf. See Paragraph 8a, which outlines that the Corps must demonstrate the federal interest (or lack thereof) "in continuing to retain the project for its currently authorized purposes based upon existing and anticipated future conditions."

[20] Decision Meeting Briefing Report at 11.

> primary users are recreational boaters and commercial passenger river cruise boats.

Further justifying the need to pursue a disposition study, the Corps adds two additional reasons:

> Since the closure of USAF, the city of Minneapolis and other stakeholders have begun planning and designing a new vision for the port area and the USAF areas; as the local vision for the area changes, there is no demand to restart commercial navigation in this waterway. Furthermore, due to the limited lock size of USAF and LSAF, allowing only two barges to lock through at a time, the demand for commercial use and tonnage of cargo has historically been low in this area.[21]

The Corps should more clearly state the problem. Based on the above text, it seems that the problem is that "limited lock size, shifting transportation needs, and declining public interest in commercial navigation have caused a precipitous drop in use of the federal infrastructure." As a response to this problem, "the Corps is conducting a Disposition Study to determine the best future use of the site."

The Conservation Organizations draw the Corps attention to deterioration, scour and stability issues at the locks and dams, as they have been outlined in the Decision Meeting Briefing Report.[22] These issues raise the risk of dam failure within the 50-year planning timeframe and should be incorporated into the problem statement to frame the issue more accurately.

If other conditions have changed since the 2017 report was published, the Corps should provide a clear explanation in the disposition study.

3.1.3.2 The project's performance history

The Decision Meeting Briefing Report details the recent use of the three locks and dams being considered for disposition and disposal, noting the decline in commercial and low recreational vessel traffic.[23] The Conservation Organizations agree that this information supports the Corps' decision to proceed with a disposition study.

The Conservation Organizations recommend the Corps also compare recreational traffic and tour boats to the far greater use of downstream locks and dams. Such a comparison will help the public understand the under-utilization of the infrastructure.

3.1.3.3 As summary of trends that indicate the extent, or limit of, the national economic development benefits

The Corps did not provide a summary of trends in its "Decision Meeting Briefing Report," but recommended that:

> the next iteration of planning this Section 216 study include a full economic analysis, including examination of all National Economic Development (NED) benefits and costs. The analysis should quantify the cost of operations,

[21] Ibid. at 35.
[22] Ibid. at 7-8.
[23] Ibid. at 38-39.

> maintenance, repair, replacement and rehabilitation; and an assessment of social, environmental, economic and recreational costs and benefits.[24]

The Conservation Organizations look forward to reviewing the Corps NED analysis and recommend the Corps incorporate the additional costs and benefits identified in this comment letter.

3.1.3.4 A forecast of future conditions and analysis of whether there may be a future need for the project or if the project "could be modified to meet future needs other than the one(s) for which the project was authorized."

The Corps' answers to this question in its four-page Focused Questions from 1st Iteration[25] (attached as Appendix J), indicates the agency does not see a future navigation need for any one of the three locks and dams, and the current navigation needs are minimal.

However, the Conservation Organizations draw the Corps' attention to an incorrect assertion that there is "significant recreational use of the project." In a presentation given by Mike Davis of the MN DNR in 2017, he cited a Corps study of recreational boating traffic in 2000 and noted that recreational boating in the reservoirs behind LD1 and LSAF was lower than anywhere else on the Mississippi River – despite the river's location within a major metropolitan area (attached as Appendix K).

As part of the Corps' analysis of future conditions, the Corps must evaluate how the lack of dredging will impact recreation boating. Given the low use of the reservoirs, what is the cost for continuing to operate and maintain each lock and dam and the navigation channel for the current users? This information is critical to weighing the value of the Corps staying or leaving and of keeping or removing the structures.

In its "Decision Meeting Briefing Report," the Corps reveals that:

> Dredging in pool 1 will be a lower priority, as few, if any commercial towboats have reason to transit Lock 1 or Lower St. Anthony Falls lock. The channel is expected to silt in, over time. The current channel markers, which are set by the U.S. Coast Guard after the Corps dredges the channel, will become unreliable for 9-foot navigation. For this analysis, it is assumed that future dredging will only be performed in Pool 1, as no commercial navigation is possible above Upper St. Anthony Falls.[26]

How is the lack of dredging already impacting recreational boating? What would justify or require dredging Pool 1 absent commercial navigation?

The Conservation Groups also request the Corps clarify how disposal of the infrastructure connects to deauthorization of related projects and how this might impact the near infinite array

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[24] Ibid. at 43.
[25] USACE. 2017-08-16. Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1 Disposition Study, Focused Questions from 1st iteration, Decision Meeting.
[26] Decision Meeting Briefing Report at 40.

of potential alternatives under a partial disposal scenario. Additionally, the Corps needs to clarify their obligations to maintain dredging operations prior to deauthorization.

In the Disposition Study of the Upper St. Anthony Falls Lock, the Corps states:

> The Rivers and Harbors Act of July 3, 1930 (Public Law 71–520) established the Upper Mississippi River nine-foot navigation channel project. The project purpose was expanded to include recreation under the Flood Control Act of 1944 (Public Law 78–534). The Rivers and Harbors Act of 1937 (Public Law 75–392) authorized the Upper and Lower St. Anthony Falls locks and dams and the Minneapolis Upper Harbor Project, which extended the 9-foot navigation channel upstream to river mile 857.6.
>
> During the study scoping, it was determined that this study will not evaluate changes to the 9-foot navigation channel. The project study team made this determination because regular maintenance dredging of the navigation channel upstream of USAF Lock and Dam no longer occurs; as such, the disposition of the authorized 9-foot navigation channel will be addressed in the follow-on disposition study of LSAF Lock and Dam and LD1.[27]

Therefore, we assume the Corps will be considering deauthorization of the 9-foot channel for all three pools in this study. The lock and dam removal alternative would require such deauthorization. In its public meetings for this scoping process, the Corps said that it will study deauthorizing the navigation mission, and that deauthorizing the navigation mission would mean the Corps will no longer maintain and dredge the channel.

Deauthorizing the navigation mission enables the full or partial disposal of LSAF and LD1, new purposes, modifications to those structures and removal. And it would allow the Corps to discontinue dredging and other channel maintenance. If deauthorized and disposed of, but not removed, what would become of the channel above each site physically and ecologically? The Corps already says it will start silting in due to reduced dredging. What will it mean for tour boats and recreational craft?

3.1.3.5 Does the project currently meet its authorized purposes? Why or why not?

In the "Decision Meeting Briefing Report," the Corps points out that the three locks and dams operated as a system, and with the closure of the USAF Lock, the ability of the other sites to meet their authorized navigation purpose was compromised. While LSAF and LD1 remain open for commercial navigation, use is restricted because the USAF Lock is closed. As the Corps has stated, the system is only partially able to meet its purpose.

The Corps makes an important point here: the three locks and dams functioned as a system to meet their authorized navigation purpose. Closing USAF broke that system. The Corps needs to clearly document whether what remains – partial commercial navigation and recreation – rises to the level of a justifiable federal need.

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[27] USACE. 2021. Upper St. Anthony Falls Lock and Dam, Section 216 Disposition Study, Draft Integrated Disposition Report and Environmental Assessment," at p. 14.

Recreation is a secondary purpose, and it cannot act as a primary reason for the Corps staying at either site unless Congress acts. The Disposition Study should address, if the dams are retained in federal ownership, how the Corps will continue to conduct lockages at LSAF and LD1 for recreational users and commercial tour operators; what the costs and benefits of doing so are; and what level of service the Corps will institute and why.

3.1.3.6 Is there reason to believe that the future condition or needs will be different from those present under the current condition? How so?

The Corps does not answer what is included in future conditions or needs in its 1st Iteration Report (2017). Without specifying which of the three locks and dams it is referring to, the Corps says, "There is currently significant recreational use of the project which is expected to continue. The current conditions are expected to continue into the future."

From this statement, it appears that Corps is saying there will not be a meaningful change in recreational use at either LSAF or LD1.

The Corps refers to recreation and an amorphous connection between residential development and a greater interest in the Gorge in its 1st Iteration Report. Here the Corps seems to be hinting that there will or could be a change. What is the direct connection between residential development and future recreational conditions or needs at either site?

If the Corps is referring to recreational use of LSAF and LD1 with regard to recreational lockages, this raises the issue of what constitutes "significant recreational use." If the Corps is counting lock visitation, then only USAF would count for significant recreational use, as LSAF sees no site visitation, and LD1 is mostly closed to onsite visitors.

The Corps needs to be specific about what site or sites it is referring to and about what defines "significant recreational use."

3.1.3.7 Are there opportunities to modify the project to serve a water resources development purpose other than the one for which it was originally authorized?

In its 1st Iteration Report (August 2017), the Corps stated the LSAF has no other water resources development purpose and said that at LD1 "Additional recreational opportunities could be added to the site." The "Decision Meeting Briefing Report" provides some clarity on what the Corps means by additional recreational opportunities by saying:

> If the recommendation is continued Corps ownership of the projects, the addition of facilities for recreation and fish and wildlife may be able to be undertaken under the authority of Section 4 of the Flood Control Act of 1944, as amended, provided there is a cost-sharing sponsor and the sponsor is willing to fund the cost of operation and maintenance of those facilities. Under this authority, preference is given to Federal, State, or local governmental agencies and is intended for suitable public park and recreational purposes.[28]

If the recommendation is to proceed with deauthorization and disposal, then recreational additions will not be possible, or at least not possible through a Corps process. The Corps has

[28] Decision Meeting Briefing Report at 51.

repeatedly stated that recreational use is not a stand-alone water resources mission. Unlike USAF, the lower two do not serve a water supply mission or a flood mitigation purpose.

3.1.3.8 Does the project pose a risk to public safety? What is the project's Dam Safety Action Classification (DSAC), if applicable? Describe the risk, including key risk drivers and uncertainties.

In its 1st Iteration Report (August 2017), the Corps stated: "With low usage, the priority for maintenance funding will be low, compared to other navigation projects, eventually leading to deterioration of the projects and decreasing the safety condition and value of the property. The current management approach is 'fix as fails.'"

It appears that if the locks and dams remain with minimal Corps staffing and funding, the sites will continue to deteriorate and become attractive nuisances and safety hazards. The Conservation Organizations noted in the Decision Meeting Briefing Report that should LD1 fail, the likelihood that the Corps would catch the failure in time to fix it is "highly unlikely."[29] The Conservation Organizations discuss these issues elsewhere herein.

For these reasons, a viable alternative use is needed, with a guarantee from any new users to adequately staff and maintain the site(s). The Disposition Study must address how the Corps will secure and maintain any elements other users do not take to ensure that the two locks and dams do not deteriorate and become safety hazards or eyesores to substantial number of visitors at surrounding parks and tourist attractions. It must also address how the Corps will vet prospective new users.

3.1.3.9 Are there environmental concerns or other controversies surrounding the project that will influence the scope and outcome of the study?

Retention or removal of locks and dams are dramatically different alternatives physically, ecologically, and socially. Therefore, the Corps needs to examine and report on the difference between these alternatives for both sites with enough detail so that the public can make an informed decision between them. The breadth and depth required by such an analysis must be done through an Environmental Impact Statement, as discussed elsewhere herein.

For LD1, the Corps stated in the 1st Iteration Report that "there would be no environmental concerns unless disposition involves removing the dam as part of a negotiated disposition agreement." Given dam removal is an alternative now under consideration in this disposition study, by the Corps' own admission there will be environmental concerns that must be addressed. And as noted above, if dredging has ended or is much more intermittent, there will be substantial physical and ecological changes in Pool 1 that need to be evaluated.

3.1.3.10 Are the real property and improvements associated with the project suitable for public uses other than water resources development? Do the real property and improvements have commercial value?

In its 1st Iteration Report, the Corps provided these answers:

[29] Id. at 8.

LSAF – Not suitable for public use, except pathway through. The city of Minneapolis has expressed interest in adding a bikeway or other path through this area; this would not include public access to the lock and dam.

L/D 1 – Yes. The space can be repurposed.

All sites - The real property and improvements do have commercial value.

Why can spaces at LD1 be repurposed but not at LSAF? Why couldn't the LSAF Lock Central Control Station and the shop and storage buildings be adaptively reused for a public purpose? The Corps needs to thoroughly consider what the other suitable public uses might be possible.

In the "Decision Meeting Briefing Report," the Corps calls out the commercial value of the hydroelectric power operations at each site. And the Corps asserts that "[I]t is likely, after going through the procedure for priority of ownership, that the outcome of the study will be a negotiated sale to Brookfield Renewable Energy, the hydropower operator at the site."[30] What did the Corps base this assertion upon and is it still true? Has Brookfield indicated any interest in ownership?

In the "Decision Meeting Briefing Report," the Corps also writes that for LD1, "A negotiated sale to Brookfield Renewable Power could be discussed when the hydropower license renewal comes due in 2034." And for LSAF, the report uses the same language, recognizing the different license termination date: "A negotiated sale to Brookfield Renewable Power could be discussed when the hydropower license renewal comes due in 2056."[31] If the Corps successfully moves forward to deauthorization and disposal without dam removal, does a sale to Brookfield need to occur before the licenses expire?

If Brookfield does not want to buy one or both sites, does a new owner or owners at one or both sites have to honor these licenses or could they negotiate new terms with Brookfield at some point?

A negotiated sale of the infrastructure would also be considered a major federal action subject to a host of environmental laws, including mitigation for degradation of the Gorge, which is a "Special Aquatic Area" and subject to additional restrictions, as discussed elsewhere herein.

3.1.3.11 Are alterations to improvements likely to be necessary in order to safely dispose of the project?

In its 1st Iteration Report (August 2017), the Corps answered this question saying: "For all sites, this will depend upon whether or not disposal involves a negotiated sale, or public sale by sealed bid or auction. A negotiated sale may involve rendering the projects safe for public use, or in the case of LSAF, possibly automating the dam gates."

Beyond and, we assume, including safety concerns, the "Decision Meeting Briefing Report," notes that "[a]s with other Corps projects disposal of the project under a negotiated sale may

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[30] Ibid at 31-32, 44.
[31] Ibid. at 48.

involve completion, by the Corps, of rehabilitation, maintenance work, or other modifications as may be specified in the agreement."[32]

The Corps needs to clarify if an entity willing to take part or all of one of the sites can negotiate whether it will address alterations for safety or whether the Corps will do that before a transfer.

In its answer to this question, the Corps also made an important point with regard to LSAF Dam: some new entity will have to take responsibility for operating and maintaining the Tainter gates, which leads to some critical questions:

- If the gates are automated, who oversees and is responsible for the automation equipment?
- How closely do the gates have to be monitored and adjusted?
- What qualifications and capacity must the new owner demonstrate prior to assuming Tainter gate management?
- We assume a new owner will be responsible for Pier house concrete, metal and mechanical repairs. Is this correct?
- Are there scour issues below LSAF that require monitoring or maintenance?

While LD1 does not have gates, some new entity would be responsible for concrete repair, scour repair and overall dam stability to ensure its safety. Given the history of dam stability issues and scour holes below the dam, what qualifications and capacity must the new owner demonstrate prior to assuming ownership of the dam?

In the "Decision Meeting Briefing Report," the Corps says, "More information concerning the capability of the entity to assume ownership will be presented at the tentatively selected plan (TSP) level of the analysis, provided the recommended action is to continue with the disposition study."[33]

The Corps needs to fully document all that any new entities would be responsible for and their capacity and capability in doing so. The reality of a new owner having the capability and capacity to take on such important public safety and publicly visible properties must be clear before choosing an alternative that involves retaining one or both locks and dams without Corps ownership.

Some project elements, like the locks, dams, and retaining walls, carry a high degree of risk and liability that a private owner or another agency may not be able to properly manage. For example, the large retaining wall at LD1 supports significant infrastructure, including Wabun Park and the Minnesota Veterans Home. Given the significant size of the structure and public infrastructure it supports, it is unlikely any private entity would be capable or willing to provide the same level of maintenance and oversight as the Corps.

Therefore, it is imperative that the Corps provide the actual operations, maintenance, rehabilitation, and major rehabilitation costs annually, going back as far as the Corps has owned and operated the infrastructure, as well as all identified repairs or improvements that can be

[32] Ibid. at 51.
[33] Id.

projected. This information is necessary to determine recurring maintenance problems that would require special expertise for any entity that might be interested in future ownership. These potential costs, liabilities, and safety concerns may lead to a determination that some components of the infrastructure cannot be safely conveyed to another entity and therefore must continue to be managed by the Corps. This provides further rationale for including partial disposition as an option in this study.

3.1.3.12 What is the annual holding cost and anticipated transaction cost, including rehabilitation required?

In its 1st Iteration Report (August 2017), the Corps provided the figures below for the annual holding costs.

USAF: $ 590,000

LSAF: $ 2,629,000

L/D 1: $ 1,621,000

Total for all three: $ 4,840,000

(Including operations, major maintenance, dredging and electrical usage).

Total LSAF L&D and L&D 1 = $4,250,000

But, in the "Decision Meeting Briefing Report," the Corps provides the following figures:[34]

Table 17 - Total Average Annual Costs

Location	Total Assumed Future Annual Costs
Upper St. Anthony Falls	$ 412,000
Lower St. Anthony Falls	$1,906,000
Lock and Dam 1	$1,055,000
Total	$3,373,000

The public needs a clear and consistent presentation of the costs of retaining the two locks and dams. This includes how the costs are calculated and what key terms like "holding costs" mean.

3.1.3.13 What other special considerations or potential liabilities exist due to retaining ownership of the project?

In its 1st Iteration Report (August 2017), the Corps stated: "With low usage, the priority for maintenance funding will be low, compared to other navigation projects, eventually leading to deterioration of the projects and decreasing the safety condition and value of the property. The current management approach is 'fix as fails.'"

The Corps made an important admission here: they will not spend enough money on the LSAF or LD1 to stave off some deterioration. If the choice is between spending Operations and

[34] Ibid. at 40-42.

Maintenance dollars on active locks and dams versus the two being studied, the Corps will choose the active lock and dams. The Corps should address the impacts to the river, national park and surrounding community that will result from allowing these projects to deteriorate where they stand.

3.1.3.14 What is the level of Congressional Interest in the project and disposition study, if any?

We know there is a high level of interest in the Mississippi River, national park site, and disposition study from Senators Amy Klobuchar and Tina Smith, as well Representatives Betty McCollum and Ilhan Omar, the latter two who represent the districts where the lock and dam structures are located.

We do not know where any Member of the Minnesota Congressional Delegation stands in terms of the outcome of the disposition study, including potential removal of either the LSAF or LD1. At an NPCA event October 5, 2022, during which representatives from the Corps were in attendance, Rep. Omar indicated interest in hearing from her constituents and having an open process for determining the disposition study's outcome.

3.1.3.15 What uncertainties need reduction in order to make a recommendation?

In its 1st Iteration Report (August 2017), the Corps stated: "A recommendation to continue with the disposition study with the intent to ultimately recommend deauthorization and disposal of the project can be made with the current data."

The Corps should outline what "current data" they are relying on to inform their recommendation to deauthorize and dispose of the project. We understand that the Corps can make a recommendation to move to disposal and deauthorization without having all the details of the consequences of doing so. However, the Corps should provide in the study details about factors it considered for its recommendation, the weight it gives to each of the factors it considered and details about any factors it excluded from consideration.

3.1.3.16 Are there any issues of interest for the vertical team to monitor and review, which would help inform the deauthorization and disposal process?

Is there any potential that the loss of the LSAF reservoir due to dam removal could affect the cutoff wall under St. Anthony Falls?

3.1.4 Other questions for Corps analysis

We also ask that the Corps examine and respond to the following questions in the study:

3.1.4.1.1 Meeker Island Lock and Dam

1. Who currently owns the Meeker Island lock and dam, remnants, including the bear trap gate structures on the west side? Was a disposition study ever completed for the structure or the structures officially transferred to another entity? If so, which entity and are the real estate documents still available?
2. What would be the impacts of the presence of the Meeker Island structure should dam removal or other alternatives change river flow and water levels? Evaluate hydrology, recreation, potential for unauthorized access and vandalism, etc.

3. What would be the cost of modifying or removing the structure to mitigate the above impacts?
4. How does the historic significance of the structure affect future removal or modification options, should they be necessary as part of some considered alternatives?

3.1.4.1.2 National Park impacts

1. The Corps should evaluate the potential impacts each alternative will have on the seven resource types identified in the Mississippi National River and Recreation Area (MNRRA) enabling legislation: historical, recreational, scenic, cultural, natural, economic, and scientific.[35] Although not specifically called out in the legislation, water resources play an extremely important role in the health of the river and park, and impacts to water resources should also be evaluated.
2. The possibility of disposal of any of the Corps' infrastructure could have enormous impacts on the national park. MNRRA must be consulted in the Corps' decision-making process pursuant to its enabling legislation.[36]

3.1.4.1.3 Ecosystem and environment

1. How would each alternative impact the movement of invasive species, including but not limited to invasive carp species (silver carp, grass carp, bighead carp)?
2. How would each alternative impact habitat in the river and along its banks in the affected area?
3. How would each alternative impact water quality?
4. What species (fish, mussel, plant, mammal) are found in Pool 1 and on its banks presently? How would each alternative impact which species are found in Pool 1 and on its banks, and in what numbers?
5. What would be the impacts to endangered species, threatened species, and species of Greatest Conservation Need, both those currently present and those that may find the area more suitable habitat under each alternative?
6. What species (fish, mussel, plant, mammal) would be likely to repopulate the area or could be introduced as part of the restoration and environmental mitigation under each alternative?
7. If dam removal were conducted, restoration of riverine habitat would need to be completed. What restoration would be needed and how much would that cost?
8. Where and how would river levels change as a result of the different alternatives? How would changed river levels under removal alternatives affect navigation (including downstream in the Minnesota River confluence and St. Paul port areas), recreation, frequency of cost of flood response and mitigation, shoreline areas, etc.?
9. How is climate change anticipated to impact river levels and flow in the next 20 years? How will the different alternatives affect management of river levels and flow in increasingly extreme flood and drought situations?

3.1.4.1.4 Sediment

1. How much sediment is impounded behind LSAF and LD1?

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[35] Public Law 100-696, Section 701(a), 102 Stat. 4599, Nov. 18, 1988.
[36] Id. at 704(b).

2. Is the sediment behind the structures polluted? What substances are in it and at what concentrations and locations? The Conservation Organizations are aware that the Corps has sampled sediment as part of their dredging program; what were the results of those studies?
3. What would be the impacts of sediment flow (navigation, recreation, ecology, etc.) in Pools 1 and 2 should sediment be released from behind LSAF or LD1? How would impacts be mitigated and at what cost?
4. How would the alternatives impact channel depth and sedimentation throughout the year at Watergate Marina in Crosby Farm Regional Park (proposed future home of the national park headquarters and the River Learning Center) and other existing marinas?
5. How much sediment is in Pool 1 versus how much the Minnesota River brings in at its confluence annually? How does the level of pollution in Pool 1 sediment compare to that from the Minnesota River?
6. The Corps dredged Pool 1 for decades. What do studies of the sediment it dredged reveal?

3.1.4.1.5 Recreation

1. How would the alternatives impact parkland along the riverbank?
2. If islands and/or additional shoreline were to form due to dam removal or other alternatives, who would own and manage that land? Do any easements exist that would apply to these newly-exposed areas?
3. How would the alternatives impact existing recreational facilities in the affected area, including the University of Minnesota and Minneapolis rowing clubs, Mississippi Gorge Regional Park, Hidden Falls-Crosby Regional Park, Minnehaha Regional Park, and other facilities?
4. At its public meetings, a display board said the Corps holds easements on 234.48 acres. What kind of easements are these and who owns the land or property in fee title? What happens to these easements if one or both of the locks and dams are removed? Also, if the 9-foot channel project and one or both of the locks and dam are deauthorized and disposed of, what happens with the easements? See Public Meeting Poster Board attached hereto as Appendix L.
5. The same display board also states that the Corps has three outgrants, where the Corps is the landowner but "has authorized the use of the property by others." What happens with these outgrants under the various scenarios described in number four immediately above?

3.1.4.1.6 Application of other rules and standards

1. The Corps should examine compatibility with the State of Minnesota Mississippi River Corridor Critical Area rules (6106.0010 – 6106.0180) for each alternative.

3.2 Compliance with Administrative Procedure Act (APA) and National Environmental Policy Act (NEPA)

The initiation of a disposition study should result in the issuance of a final decision and recommendation, regardless of the outcome. Conservation Organizations are concerned about a national trend whereby the Corps initiates a disposition study on a major piece of infrastructure, such as a federal dam, but then discontinues the study without giving the public an opportunity to weigh in on the decision.[37] This trend is concerning to Conservation Organizations because the decision to retain a piece of infrastructure and continue operations and maintenance of the infrastructure is "the consummation of the decision-making process" … "from which legal consequences will flow." Bennett v. Spear, 520 U.S. 154, 177–178 (1997). This includes "an activity or decision subject to Federal control and responsibility…" and "may include new and *continuing activities*." 40 CFR 1508.1(q) (emphasis added).

Examples of legal consequences that would flow from deciding to maintain the infrastructure and "continuing activities" may include hydroelectric generating licenses, dam safety plans, recovery outlooks for protected and/or at-risk species, internal and external costs to mitigate environmental impacts, and other legal consequences. The Corps must disclose disposition study findings in order to comply with all relevant obligations under the Administrative Procedure Act, the National Environmental Policy Act, and other federal environmental laws like the Clean Water Act and Endangered Species Act. The Corps' infrastructure has and continues to have tremendous impacts on the environment that deserve to be properly analyzed and mitigated in the context of disposition, even if the Corps determines that it is in the federal interest to retain the structures.

To fully comply with NEPA, APA, and other environmental laws, the Corps must:

1. Comply with NEPA by initiating an Environmental Impact Statement for the disposition study;
2. Comply with the Water Resources Development Act by selecting the alternative that protects and restores the environment;
3. Comply with the Clean Water Act by incorporating mitigating damages to aquatic resources under relevant alternatives;
4. Comply with the Endangered Species Act through consultation with the U.S. Fish and Wildlife Service; and
5. Comply with the relevant guidance and executive orders related to Tribal Coordination.

3.2.1 The Corps must initiate an Environmental Impact Statement to comply with NEPA.

The Corps must initiate an Environmental Impact Statement (EIS). The Corps' procedures for implementing NEPA state that an EIS is required when the Corps considers "[p]roposed major changes in the operation and/or maintenance of completed projects." The very nature and purpose of the Disposition Study is to consider a "major change in the operation and/or maintenance of a completed project." As such, the Corps must automatically initiate the Environmental Impact Statement process. According to the Corps NEPA implementation guidance, an EIS must be the default action when considering "major changes in the operation and/or maintenance of completed projects" until and unless "early studies and coordination show that a particular action is not likely to have significant impact on the quality of the human

[37] Phadke, R, M Adamson, and Bruce Braun. June 30, 2022. Mississippi Disposition. Viewed on December 16, 2022. Available at https://sites.google.com/macalester.edu/disposition/other-studies?pli=1

environment."[38] To date, the Corps has only initiated the less-rigorous Environmental Assessment process, in violation of the Corps procedures for implementing NEPA.

In addition to the Corps' obligation to initiate an EIS by default, *all* alternatives the Corps is considering will have significant environmental impacts. Continuing to impound the Mississippi River has significant environmental impacts, impacts that have never been mitigated. These impacts are profoundly detrimental to the environment of the Mississippi River and the hundreds of species that use the river. As such, any decision to continue to impound the Mississippi River will perpetuate those same impacts.

The Council on Environmental Quality (CEQ) has made clear, in situations like those in the Mississippi River where the environment has already been greatly modified by human activities, it is not sufficient to compare the impacts of the proposed alternative against the current conditions. Instead, the baseline must include a clear description of how the health of the resource has changed over time to determine whether additional stresses will push it over the edge.[39] As such, the Corps must evaluate all project alternatives in terms of the historic health of the Mississippi River and how the additional stress of continuing to operate the dams will influence ecosystem health.

There is a large body of scientific evidence that indicates the dams are a primary cause of ecological decline on the Mississippi River. This has been widely accepted for over half a century. Following litigation bought by the Izaak Walton League in the 1970s, Congress ordered a more thorough review of the impacts of the navigation system on the Upper Mississippi River. In 1982, the Congressionally established Upper Mississippi River Basin Commission found that "[t]he navigation project and navigation traffic significantly affect the ecosystem of the [Upper Mississippi River System]." Impacts included "operation and maintenance of the [navigation] project," including the dams.[40] In response to these findings, Congress established the Upper Mississippi River Restoration Program in 1986, which includes habitat rehabilitation and enhancement projects and long-term resource monitoring.

Since 1986, only 5-percent of lost habitat on the Upper Mississippi River has been "rehabilitated" and a plethora of studies from the long-term resource monitoring program (LTRMP) indicate that the Mississippi River ecosystem continues to be at risk. The LTRMP's data have been examined in several hundred technical reports, peer-reviewed publications, and publicly available management tools and models.[41]

Relying on the LTRMP's data, the Corps has admitted that "conditions at even the most healthy sites within the [UMRS] are at least partially artificial, non-sustainable, and in a recognized

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[38] 33 C.F.R. 230.6.

[39] Council on Environmental Quality, Considering Cumulative Effects Under the National Environmental Policy Act at 41 (January 1997).

[40] Upper Mississippi River Basin Commission. 1982. Comprehensive Master Plan for the Upper Mississippi River System.

[41] Upper Mississippi River Restoration Program Long Term Resources Monitoring. Reports and Publications. Last Updated November 18. 2022. Viewed November 22, 2022. Available at https://www.umesc.usgs.gov/reports_publications/ltrmp_rep_list.html

state of degradation."[42] In 2016, the Corps advised Congress that "habitat within the Upper Mississippi River is degrading at a rate of one to three percent annually. At these rates, the ecosystem is declining one to four times faster than currently [sic] restoration efforts."[43]

The LTRMP's 2022 Report found that none of the ecological indicators "meets desired condition" in the Upper Impounded Reach (which represents the area that includes Lower St Anthony Falls Lock and Dam and Lock and Dam 1). Additionally, the two "most important" ecological indicators (lentic area and lotic structure) both "deviate from desired conditions" and "may merit actions to improve." Impoundment is among the primary drivers of decline for these ecological indicators.[44]

Given the well-documented, severe, and persistent impacts of impounding the Mississippi River, the Corps must conduct an EIS to evaluate the ecosystem consequences of a decision to retain the Lower St. Anthony Falls Lock and Dam and Lock and Dam 1.

3.2.1.1 Considerations for Direct, Indirect, and Cumulative Impacts

In comparing and analyzing potential alternatives, the EIS must examine, among other things, the direct, indirect, and cumulative environmental impacts of alternatives, the conservation potential of those alternatives, and the means to mitigate adverse environmental impacts that cannot be avoided.[45] This assessment is essential for determining whether less environmentally damaging alternatives are available. Direct impacts are caused by the action and occur at the same time and place as the action. Indirect impacts are also caused by the action, but are later in time or farther removed from the location of the action.[46] Cumulative impacts are "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."[47] The cumulative impacts analysis ensures that the agency will not "treat the identified environmental concern in a vacuum."[48]

The cumulative impacts analysis must examine the cumulative effects of federal, state, and private projects and actions.[49] The cumulative impacts analysis must also evaluate the cumulative impacts of climate change.[50] This evaluation is extremely important as: "Climate

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[42] USACE. 1997. Report to Congress: An Evaluation of the Upper Mississippi River System Environmental Management Program. Available at https://www.mvr.usace.army.mil/Portals/48/docs/Environmental/UMRR/EMP_RTC_1997.pdf
[43] USACE. 2016. Report to Congress: Upper Mississippi River Restoration Program.
[44] USGS. 2022. Ecological Status and Trends of the Upper Mississippi and Illinois Rivers.
[45] 40 C.F.R. § 1502.16.
[46] 40 C.F.R. § 1508.8.
[47] 40 C.F.R. § 1508.7.
[48] Grand Canyon Trust v. FAA, 290 F.3d 339, 346 (D.C. Cir. 2002).
[49] The requirement to assess non-Federal actions is not "impossible to implement, unreasonable or oppressive: one does not need control over private land to be able to assess the impact that activities on private land may have" on the project area. Resources Ltd., Inc. v. Robertson, 35 F.3d 1300, 1306 (9th Cir. 1993).
[50] See Center for Biological Diversity v. Nat'l Hwy Traffic Safety Administration, 538 F.3d 1172, 1217 (9th Cir. 2008) (holding that analyzing the impacts of climate change is "precisely the kind of cumulative

change can increase the vulnerability of a resource, ecosystem, or human community, causing a proposed action to result in consequences that are more damaging than prior experience with environmental impacts analysis might indicate… [and] climate change can magnify the damaging strength of certain effects of a proposed action." … "Agencies should consider the specific effects of the proposed action (including the proposed action's effect on the vulnerability of affected ecosystems), the nexus of those effects with projected climate change effects on the same aspects of our environment, and the implications for the environment to adapt to the projected effects of climate change."[51]

The EIS must provide "quantified or detailed information" on the impacts, including the cumulative impacts, so that the courts and the public can be assured that the Corps has taken the mandated hard look at the environmental consequences of the Project.[52] If information that is essential for making a reasoned choice among alternatives is not available, the Corps must obtain that information unless the costs of doing so would be "exorbitant."[53]

Importantly, as CEQ has made clear, in situations like those in the Mississippi River where the environment has already been greatly modified by human activities, it is not sufficient to compare the impacts of the proposed alternative against the current conditions. Instead, the baseline must include a clear description of how the health of the resource has changed over time to determine whether additional stresses will push it over the edge.[54]

The EIS should examine the direct, indirect, and cumulative impacts of all reasonable alternatives on at least the impacts discussed below.

- Impacts on fish and wildlife. The EIS must examine the impacts of the alternatives on the species that utilize the Mississippi River, including the impacts to fish, waterfowl, birds, mammals, reptiles, amphibians, and mussels. The Mississippi River is used by an astounding array of wildlife, including 360 species of birds, 260 species of fish, 145 species of amphibians and reptiles, 98 species of mussels, and 50 species of mammals. Forty percent of North America's waterfowl migrate through the Mississippi River flyway. The impacts on the critical array of migratory species that utilize the Mississippi River and Mississippi River flyway must also be analyzed, including the cumulative

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impacts analysis that NEPA requires agencies to conduct" and that NEPA requires analysis of the cumulative impact of greenhouse gas emissions when deciding not to set certain CAFE standards); Center for Biological Diversity v. Kempthorne, 588 F.3d 701, 711 (9th Cir. 2009) (NEPA analysis properly included analysis of the effects of climate change on polar bears, including "increased use of coastal environments, increased bear/human encounters, changes in polar bear body condition, decline in cub survival, and increased potential for stress and mortality, and energetic needs in hunting for seals, as well as traveling and swimming to denning sites and feeding areas.").

[51] Council on Environmental Quality, Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions (February 18, 2010). The CEQ guidance makes it clear that analyzing the impacts of climate change is not restricted to evaluating whether a project could itself exacerbate global warming. The magnifying and additive effects of global warming also must be evaluated.

[52] Neighbors of Cuddy Mountain v. U. S. Forest Service, 137 F.3d 1372, 1379 (9th Cir. 1998); Natural Resources Defense Council v. Callaway, 524 F.2d 79, 87 (2d Cir. 1975).

[53] 40 C.F.R. § 1502.22

[54] Council on Environmental Quality, Considering Cumulative Effects Under the National Environmental Policy Act at 41 (January 1997).

impacts of climate change on these species. Migratory wildlife is particularly vulnerable to the impacts of climate change. An accurate assessment of fish and wildlife impacts will require an accurate assessment of impacts to the full range of habitats that these species rely on. A meaningful assessment would also include an evaluation of the impacts of each alternative on the ability of the fish and wildlife that utilize the river and flyway to withstand the adverse impacts of climate change (i.e., the species' resiliency to climate change).

- Impacts on endangered species. The EIS should pay particular attention to the impacts on threatened and endangered species and any critical habitat. This should include an analysis of impacts to recently listed species (for which there currently is no biological opinion) and to species covered by the "Tier 1 Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel in the Upper Mississippi River System." The Conservation Organizations urge the Corps to initiate formal consultation under the Endangered Species Act and demonstrate full compliance with all conditions established in the Tier I biological opinion.
- The Department of Natural Resources (DNR) conducted fish surveys in Pool 1 and the LSAF Pool in 1982, 1995 and 2009, and conducted telemetry studies of Pool 2 beginning in 2013.[55] All these studies demonstrate how negatively the reservoirs of the Gorge have affected the native fish populations. The DNR also undertook fish surveys of the Gorge in 2022 but has not released the results. The Corps needs to work with the DNR, using all their fisheries studies, to clearly convey to the public the differences between the fishery with and without the locks and dams. In addition, Luther Aadland, while with the DNR, conducted a number of studies looking at the impact of dams in Minnesota on native fish populations and the response of those fish populations to dam removal. The Corps needs to incorporate Aadland's studies into its NEPA studies.[56]
- Impacts on key habitats – including riffle-pool complexes, mid-channel bars, braided river habitat, riverine wetlands, and floodplain wetlands. The Mississippi River and its floodplain have also suffered astounding wetland losses. The loss of these vital habitats has cascading negative impacts on fish and wildlife, public safety, recreation, and economies that rely on healthy river and floodplain systems. The EIS must carefully evaluate and quantify the potential for additional losses – or gains – of backwater areas, natural side channels, crossover habitat, mid-channel bars, riverine wetlands and

[55] Minnesota Department of Natural Resources. Fisheries Management. Standard Lake Survey Report, US Lock & Dam #1 Pool (8/10/2009); Minnesota Department of Natural Resources. Fisheries Management Standard Lake Survey Report, US Lock & Dam #1 Pool (9/22/2011); Polomis, Taylor. Population Assessment, Lock & Dam No. 1 to Coon Rapids Dam. Minnesota Department of Natural Resources (August 8-30, 1995); Stiras, Joel K. Minnesota Department of Natural Resources. Division of Fish and Wildlife, Section on Fisheries. Major Rivers Survey Report. East Metro Area Rivers Telemetry Project (2017).

[56] Aadland, Luther. "Barrier Effects on Native Fishes of Minnesota." Minnesota Department of Natural Resources, Division of Ecological and Water Resources (March 2015); Aadland, Luther. "Reconnecting Rivers: Natural Channel Design in Dam Removal and Fish Passage." First Edition. Minnesota Department of Natural Resources, Division of Ecological Resources Stream Habitat Program (January 2010).

floodplain wetlands. The cumulative impacts of historical losses to these key habitats must also be fully evaluated and accounted for in any final recommended alternative.

- Impacts from sedimentation. Sedimentation is one of the most significant problems caused by impoundment of the Mississippi River. The EIS must carefully evaluate and quantify the impacts of each alternative on: increasing sedimentation in vital habitats; relocating sedimentation problems (i.e., shifting the loci of sedimentation which could eventually lead to even more river training structure construction and dredging); and altering sediment transport downstream.
- Impacts on water quality, including nutrient composition. The Mississippi River remains plagued by water quality problems, including excess nutrients that have both local and ecosystem wide impacts (including, for example, yearly development of the Gulf of Mexico dead zone). The EIS must carefully evaluate and quantify the impacts of each alternative on water quality in the river, including the potential water quality impacts caused by loss of backwater habitats and wetlands and increased sedimentation.
- Cumulative impacts of climate change. As discussed above, the EIS must assess the cumulative impacts of climate change, including climate-change induced increases in precipitation and extreme weather events, on the direct and indirect impacts of each alternative. Of critical concern are the additive and magnifying effect of climate change on increased flood risks and on harm to migratory species.
- Additionally, the Corps needs to provide information on the public safety risk should Lock and Dam 1 and/or Lower St. Anthony Falls Lock and Dam fail. Climate change induced extreme precipitation events threaten dam and levee infrastructure, which can have catastrophic consequences.
- Impacts on ecosystem services provided by a healthy Mississippi River and floodplain. "Ecosystem services" are the goods and services produced by ecosystems that benefit humankind. These services include (but are by no means limited to) such things as carbon sequestration, wildlife habitat, nutrient retention, and erosion reduction. While these services have traditionally been undervalued because they often fall outside of conventional markets and pricing, society is increasingly recognizing the essential link between healthy ecosystems and human welfare and significant progress has been made in the science of ecosystem services evaluation. The EIS should carefully assess the impacts of each alternative on ecosystem services. The Conservation Organizations refer the Corps to the three ecosystem services valuations attached at Appendix H of these comments for information on preparing a meaningful ecosystem services valuation and for examples of ecosystem services valuations carried out in the Mississippi River Valley.
- Impacts on recreational fishing and tourism industries that rely on a healthy Mississippi River and floodplain. Mississippi River tourism generates approximately $2 billion annually. Recreational opportunities, including recreational fishing, are vitally important to the public. The EIS should fully evaluate the impacts of each alternative on these important activities.
- Impacts on bridges, stormwater water, drinking water and other public infrastructure. Bridges in the project area are owned by various entities, and except for the 35W Bridge, all have one or more piers in the river. These include: The Stone Arch Bridge owned by the Minnesota Department of Transportation (MnDOT); 35W owned by MnDOT; 10th

Avenue, owned by Minneapolis; a large-diameter drinking water transmission main that runs under the river just downstream of this bridge; Bridge Number 9 owned by Minneapolis; Washington Avenue bridge owned by Hennepin County; I-94 owned by MnDOT; Franklin Avenue, owned by Hennepin County (this bridge has a large-diameter Minneapolis drinking water transmission main suspended underneath the bridge); Short Line owned by Canadian Pacific Railway; Lake Street owned by Hennepin County; Ford Parkway owned by Hennepin County.

3.2.2 The Corps must comply with the Water Resources Development Act (WRDA) by selecting the alternative that protects and restores the environment.

WRDA 1990 changed the Corps' fundamental mission to "include environmental protection as one of the primary missions of the Corps of Engineers in planning, designing, constructing, operating, and maintaining water resources projects."[57] The National Water Policy established by Congress in 2007 requires the Corps to operate and maintain the UMR-IWW navigation system to protect the Mississippi River and its floodplain. That policy states that "all water resources projects" shall "protect[] and restor[e] the functions of natural systems and mitigat[e] any unavoidable damage to natural systems."[58]

Executive Orders issued in 1977 direct agencies to protect wetlands and floodplains. Executive Order 11990 (Protection of Wetlands) directs each federal agency to provide leadership and take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values in carrying out agency policy. Executive Order 11988 (Floodplain Management) directs each federal agency to avoid, to the extent possible, the long and short-term adverse impacts associated with the occupancy and modification of floodplains; to avoid direct and indirect support of floodplain development wherever there is a practicable alternative; and "to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

As a result, the Disposition Study must also evaluate alternatives that would protect and restore the natural functions of the Mississippi River, including wetlands and floodplains. The Corps must ultimately select an alternative that achieves these objectives.

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[57] 33 U.S.C. § 2316.

[58] 33 U.S.C 1962-3. Established by § 2031(a) of the Water Resources Development Act of 2007, and immediately applicable to all water resources projects. Enhancement of the environment has been an important federal objective for water resources programs for decades. Corps regulations in place since 1980 state that: "Laws, executive orders, and national policies promulgated in the past decade *require* that the quality of the environment be protected and, where possible, enhanced as the nation grows. . . . *Enhancement of the environment is an objective of Federal water resource programs* to be considered in the planning, design, construction, and operation and maintenance of projects. Opportunities for enhancement of the environment are sought through each of the above phases of project development. Specific considerations may include, but are not limited to, actions to preserve or enhance critical habitat for fish and wildlife; maintain or enhance water quality; improve streamflow; preservation and restoration of certain cultural resources, and the preservation or creation of wetlands." 33 C.F.R. § 236.4. (emphasis added).

3.2.3 Comply with the Clean Water Act by incorporating mitigating damages to aquatic resources under relevant alternatives.

WRDA 2007 created a new federal water policy that requires all Corps projects to protect and restore the environment and imposes new and important mitigation requirements for Corps projects, including existing projects that are re-evaluated through an EIS or supplemental EIS.[59] Under these new laws, should the Corps decide to retain Lock and Dam 1 and/or Lower St. Anthony Falls Lock and Dam, the impacts of impoundment must be mitigated.

In 2007, Congress enacted strict mitigation requirements for Corps civil works projects applicable to all proposals submitted to Congress or re-evaluated under NEPA.[60] These include enhanced mitigation requirements established for the Clean Water Act's section 404 regulatory program, which were substantially modified in 2008.[61] Congress also established a new federal water policy requiring all Corps projects to protect and restore the environment and avoid harming floodplains.[62]

Section 2283(d) of WRDA requires mitigation plans "for damages to ecological resources, including terrestrial and aquatic resources, and fish and wildlife losses," resulting from federal water resources projects.[63] Between 1986 and 2007, this requirement applied only when the Corps submitted a "proposal for the authorization of any water resources project to the Congress in any report" in which the proposal – absent mitigation – would result in a greater than "negligible adverse impact" on ecological resources and wildlife.[64] In 2007, Congress amended section 2283(d)(1) to also require mitigation plans in "any report" that "select[s] a project alternative," without limiting that requirement to reports to Congress.[65] Congress did so by adding this bolded language:

> After November 17, 1986, the Secretary shall not submit any proposal for the authorization of any water resources project to Congress in any report, **and shall not select a project alternative in any report,** unless such report contains [either a mitigation plan or a determination that any adverse ecological effects would be negligible].[66]

Once triggered, Section 2283 requires the Corps to provide a detailed mitigation plan with many specified components.[67]

As such, the Corps must develop a detailed mitigation plan for those alternatives with significant impacts to the environment. Notably, the Corps must develop a detailed mitigation plan for the alternatives that retain the dam(s) as those alternatives will have significant impacts to a "special aquatic site," as outlined below.

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[59] 33 U.S.C. § 2283(d).
[60] WRDA of 2007 (P.L. 110-114), § 2036, 33 U.S.C. § 2283(d).
[61] 33 C.F.R. Parts 325 and 332, 40 C.F.R. Part 230
[62] WRDA of 2007 § 2031, 42 U.S.C. § 1962-3.
[63] 33 U.S.C. § 2283(d)(1).
[64] Id. (1986).
[65] See Pub. L. No. 110-114, 2036(a)(1).
[66] Id.
[67] 33 U.S.C. § 2283(d)(3)(B)(i)-(vi).

3.2.3.1 Impacts of impoundment on aquatic resources

Where the Corps considers retention of one or both dams, the Corps must evaluate those impacts and develop a detailed maintenance plan as part of the EIS.

A 2008 Report[68] explains the impacts of impoundment on the Mississippi River:

> The overall effect on the impounded reaches has been to effectively remove the lower water elevations experienced during the pre-dam period. This has two primary effects, permanently inundating the area immediately behind each dam and reducing current velocities behind the dams. Reduced current velocities promote increased sedimentation rates and filling of impounded areas and backwaters. The permanently inundated areas no longer experience the annual cycle of wetting and drying that existed before dam construction, which has resulted in substantial losses of aquatic vegetation along shorelines and in shallow wetland areas. In addition, the open expanses of water above dams are now subjected to the erosive force of wind-induced waves, which has resulted in loss of islands and filling of deeper areas by sediment in these zones. The physical changes in hydrology produced by the dams were essentially immediate. The resulting geomorphic changes (loss of islands and reduced depth diversity) were probably rapid immediately after the dams were built, but are now occurring at slower rates.

All these impacts are seen in the reservoirs behind Lock and Dam 1 and Lower St. Anthony Falls. Prior to impoundment, the river between St. Anthony Falls and the Minnesota River confluence was a stretch of broken limestone known as the Mississippi River Gorge for its narrow floodplain and steep valley, dropping over 100-feet in just 10 miles.

The Gorge was once one of four big river rapids on the Upper Mississippi River, the others historically located in Rock Island, IL, Keokuk, IA and St. Louis, MO. Of the four, only a remnant of the St. Louis "Chain of Rocks" rapids remains today. These rapids were "a critical spawning area for many fish species including species that are now rare in the region…"[69] (See also Appendix M). Such Mississippi River rapids ecosystems clearly meet the criteria to be considered a "riffle and pool complex" subject to additional protection and mitigation requirements as "Special Aquatic Sites" under the Clean Water Act.[70] The impoundment of the Mississippi River Gorge creates an ongoing discharge of fill material (i.e. sedimentation) that has eliminated portions of and threatens to eliminate all the riffle and pool areas in the Gorge. Elimination of riffle and pool complexes may cause a cascading impact on aquatic resources:

> Possible loss of values: Discharge of dredged or fill material can eliminate riffle and pool areas by displacement, hydrologic modification, or sedimentation. Activities which affect riffle and pool areas and especially riffle/pool ratios, may reduce the aeration and filtration capabilities at the discharge site and

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[68] USGS. 2008. Status and Trends of the Selected Resources of the Upper Mississippi River System: A Synthesis Report of the Long Term Resources Monitoring Program.
[69] Lenhart, Christian. 2012. Restoration of the Mississippi River Gorge: Issues and Research Needs. *Restoration Ecology*. 30:3.
[70] *See* 40 CFR 230.45(a)-(b).

> downstream, may reduce stream habitat diversity, and may retard repopulation of the disposal site and downstream waters through sedimentation and the creation of unsuitable habitat. The discharge of dredged or fill material which alters stream hydrology may cause scouring or sedimentation of riffles and pools. Sedimentation induced through hydrological modification or as a direct result of the deposition of unconsolidated dredged or fill material may clog riffle and pool areas, destroy habitats, and create anaerobic conditions. Eliminating pools and meanders by the discharge of dredged or fill material can reduce water holding capacity of streams and cause rapid runoff from a watershed. Rapid runoff can deliver large quantities of flood water in a short time to downstream areas resulting in the destruction of natural habitat, high property loss, and the need for further hydraulic modification.[71]

Indeed, working with biologists at the Minnesota DNR, Conservation Organizations identified over 50 species of rare, threatened, and endangered plants and animals whose habitat historically overlapped with the Gorge. Based on available information, the construction and ongoing maintenance of the reservoirs behind Lower St. Anthony Falls Lock and Dam and Lock and Dam 1 may be a factor in the status of these species. Of those 50+ species, at least a dozen rare, threatened, and endangered species recovery outlooks would likely be significantly improved if the dams were removed (see attached hereto as Appendix N). According to biologist, Mike Davis, of the Minnesota Department of Natural Resources Center for Aquatic Mollusk Programs, removal of the dams could restore “unique riverine habitat” that “could once again support the federally Endangered Winged Mapleleaf, Spectaclecase, Snuffbox, Higgins’ Eye and Sheepnose mussels” and “could increase the likelihood of recovering and delisting these species” (see attached hereto as Appendix O).

Should the Corps decide that retaining the dams are in the national interest, the 404(b)(1) Guidelines require the Corps to take *all* appropriate and practicable steps to minimize and compensate for the project’s adverse impacts on the aquatic ecosystem.[72] The Corps is also required to calculate the appropriate compensatory mitigation amount by taking into consideration such relevant factors as the method of compensation, the likelihood of success, differences between lost functions at the impact site and mitigation site, and the difficulty of restoring aquatic resources, to name a few.[73]

Each alternative must include mitigation for any unavoidable adverse impacts as required by 33 U.S.C. § 2283(d) and the Clean Water Act. These mitigation actions and costs must be included in the disposition study as part of the project alternative evaluation under those options that retain both or one of the dams. The costs of mitigation must be incorporated into operation and maintenance expenses and a detailed mitigation plan must be included as part of the EIS.

[71] 40 CFR 230.45(b).
[72] 40 C.F.R. § 230.10(d).
[73] *See* 40 C.F.R. § 230.93(f)(2).

3.2.4 The Corps must initiate formal consultation with the U.S. Fish and Wildlife Service to comply with the Endangered Species Act.

In May 2000, the U.S. Fish and Wildlife Service issued a Final Biological Opinion on the Corps' O&M activities which concludes that the "continued operation and maintenance of the 9-foot Navigation project will jeopardize the continued existence of the Higgins eye pearly mussel (Lampsilis higginsi)..."[74] The Higgins eye pearly mussel was found in the Gorge prior to impoundment, is still present around the St. Croix and Mississippi River confluence, and would likely thrive at the site if the dams were removed to allow restoration of the Mississippi River Gorge.

As mentioned above, Conservation Organizations identified over 50 species of rare, threatened, and endangered plants and animals whose habitat historically overlapped with the reservoirs behind Lower St. Anthony Falls Lock and Dam and Lock and Dam 1. Of those 50+ species, there are six federally listed species that would likely be impacted by the outcome of the Disposition Study. Those species include the northern long-eared bat, winged mapleleaf mussel, spectaclecase mussel, snuffbox mussel, sheepnose mussel, and Higgin's eye pearly mussel.

Due to the likely presence of and impacts to multiple federal threatened and endangered species, the Corps must immediately initiate consultation with the U.S. Fish and Wildlife Service to comply with the Endangered Species Act.

3.2.5 The Corps must initiate formal consultation with the Dakota and Ojibwe Tribal Nations to comply with Executive Order 13175.

Any study outcome must fully incorporate the needs of the Dakota and Ojibwe communities and their relationship with the sacred sites that will be impacted by the Disposition Study. There are at least two sites that may be impacted by the outcome of the Disposition Study that are sacred to the Dakota and Ojibwe nations — Spirit Island and Bdote Mnisota. Also there is evidence that the entire stretch of the Mississippi River between the Falls and the confluence of the Mississippi and Minnesota River was sacred to the ancestors of the modern Dakota and Ojibwe.[75] Many Dakota and Ojibwe community members today still consider this area sacred.

Lock and Dam No. 1 is just 3.5 miles upstream from the confluence, and access and use of the Bdote sacred site may be impacted by the outcome of the Disposition Study. While the site is technically outside the footprint of the proposed project, the use of the site could be impacted in ways that should be considered in the study. Spirit Island is located below St. Anthony Falls. This sacred site may be significantly impacted by the outcome of study. Spirit Island, which was made of rare Platteville limestone, was quarried by colonists and the stone jetty that runs along the channel of the Upper Lock sits on top of the footprint of Spirit Island. If the two dams below the falls are removed, some remaining portion of Spirit Island (or its footprint) might be exposed. The potential significance that action may have on the Dakota and Ojibwe communities needs to be taken into consideration by the Corps.

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[74] U.S. Fish and Wildlife Service, Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System at 1.
[75] Pennefeather, S.M. 2003. Mill city: a visual history of the Minneapolis mill district. St. Paul MN: Minnesota State Historical Society.

Executive Order 13175 mandates federal agencies "have an accountable process to ensure meaningful and timely input by tribal officials…" This process includes transferring funds to the impacted tribes to cover the direct costs of coordination, consulting with tribes early in the process, and post a tribal summary impact statement in the Federal Register, among other requirements.[76]

St. Anthony Falls has migrated upstream from the Minnesota River confluence over thousands of years. Consequently, the Dakota and other tribes likely visited it at many different places; therefore, the whole Gorge should be evaluated under the National Historic Preservation Act and all appropriate studies completed, including a Traditional Cultural Property (TCP) review. This review should include the TCP study being done for USAF.

Pursuant to the special relationship between the Federal government and Federally recognized Native American tribes, and Section 101(d)(6)(B) of the NHPA and 36 CFR § 800.2(c)(2)(ii), the Corps is responsible for government-to-government consultation with Federally recognized Native American tribes, and the Corps should consult with all tribes that may have connections to the Gorge.

Because the outcome of the Disposition Study may include proposing legislation (such as deauthorizing the dams) that will impact these sites, the Corps must comply with Executive Order 13175.

3.2.6 The Corps must comply with the National Historic Preservation Act.

The National Historic Preservation Act (NHPA)[77] directs federal agencies to take a leadership role in the nation's preservation efforts, and to make informed decisions about the administration of federally owned or controlled historic properties. The NHPA includes a number of directives to federal agencies, the primary of which are subsumed under section 106 (16 U.S.C. 470f) and section 110 (16 U.S.C. 470h). Section 106 (16 U.S.C. 470f) of the NHPA states:

> The head of any Federal agency having direct or indirect jurisdiction over a proposed Federal or federally assisted undertaking in any State and the head of any Federal department or independent agency having authority to license any undertaking shall, prior to the approval of the expenditure of any Federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places. The head of any such Federal agency shall afford the Advisory Council on Historic Preservation…a reasonable opportunity to comment with regard to such undertaking.

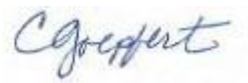
In short, section 106 (16 U.S.C. 470f), and its implementing regulations (36 C.F.R. part 800) requires federal agencies to consider the effects of their undertakings on historic properties prior to implementation.

[76] Executive Order 13175 Section 5.
[77] Pub. L. No. 102-575, 16 U.S.C. 470.

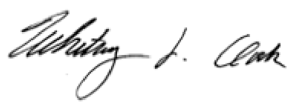
3.3 SUMMARY

We thank you for the opportunity to submit these comments. We request that the Corps release the final scope for the disposition study as soon as possible and *prior* to completion and public review of the draft study.

4 SIGNATURES



Christine Goepfert, Midwest Campaign Director
National Parks Conservation Association



Whitney L. Clark, Executive Director
Friends of the Mississippi River

Olivia Dorothy, Restoration Director
American Rivers

American Rivers, Friends of the Mississippi River, National Parks Conservation Association Appendices

MACALESTER

ENGAGEMENT MATTERS: Public Understandings of River Infrastructure

Report submitted to the U.S. Army Corps of Engineers regarding their Upper Mississippi Disposition Scoping Process

DECEMBER 2022

ACKNOWLEDGEMENTS

This report was written by Dr. Roopali Phadke, with assistance from Nili Barnoon, Rebecca Driker-Ohren, Romeo Gomes, Zella Lobo, and Amber Wiedenhoeft.

We would like to thank our collaborators at American Rivers, Friends of the Mississippi River, Mississippi Park Connection, National Park Service, National Parks Conservation Association, Paddle Bridge and the Saint Paul Public Library for their partnership. We extend our gratitude to historian Dr. John Anfinson for sharing his knowledge and expertise. Thanks also to Kalen Keir, Tom Reiter and David Wheaton for their photography.

We appreciate that staff from the St. Paul District of the Army Corps of Engineers have collaborated with us throughout our study period.

OUR PROJECT

The U.S. Congress charges the Army Corps of Engineers to conduct disposition studies to determine whether a project that they operate and maintain should be deauthorized and ultimately disposed of. The Corps is in the midst of conducting disposition studies from coast to coast. This process includes gauging public opinion through hearings and public comments.

Since 2020, we have been examining the Corps' ongoing study of the Upper Mississippi, which includes the three uppermost locks and dams on the river (Upper St. Anthony Falls, Lower St. Anthony Falls and Lock and Dam 1). Beyond the Mississippi, we are examining the outcomes of disposition studies on other American rivers.

You can find out more information about our project, including our public opinion surveys and public arts projects, on our website: **https://sites.google.com/macalester.edu/disposition/home**.

This project is funded by the National Science Foundation (SES#1947152). If you have any questions about the research study, please contact Dr. Roopali Phadke, [redacted]

*Cover image from Paddle Bridge kayak tour of Lock and Dam 1.

I. INTRODUCTION

Throughout June and July of 2022, our research team collected 233 surveys from Twin Cities community members regarding their understanding of lock and dam infrastructure and their opinions on the future of the Lower Saint Anthony Falls Lock and Dam (LSAF L & D) and Lock and Dam No. 1 (L & D 1). Although this is a relatively small sample size, it exceeds the 199 public comments the Army Corps of Engineers received during their Upper Saint Anthony Falls Disposition Study comment period.

We collected these surveys during a series of walking, biking, kayaking, and boat focus group tours which included 3 community council tours, 2 BIPOC (Black, Indigenous and people of color) tours, and 1 youth-centered tour. Our team partnered with the Friends of the Mississippi River, National Park Service, National Parks Conservation Association, Mississippi Park Connection and St. Paul Public Library to broaden our outreach and the expertise offered to participants.

This report shares the insights we gained from hosting focus group tours and the conclusions we have drawn from post-tour participant surveys. We hope this will serve as guidance for the Corps' public engagement processes on future disposition studies, including the LSAF L & D and L & D 1 Disposition Study. In particular, we hope to highlight what we think are effective ways to prime public interest and knowledge on the topic. We also provide guidance on increasing the diversity and inclusivity of the Corps' engagement strategy.

II. METHODS & DEMOGRAPHICS

We had over 400 applicants for our 2022 public tours. We used diverse outreach methods for sharing information about these tours with the help of our partners. This involved distributing posters in public spaces including restaurants and corner shops, and posting to our social media pages and our partners' social media to communicate about our project, survey, and focus group tours. Across all tours, we aimed for inclusivity in terms of race, ethnicity, gender, sexuality, age, and knowledge about lock and dam infrastructure. We asked community members to provide demographic information on their tour request forms and combed through the data to carefully select as diverse groups as possible for each tour date.

We partnered with Friends of the Mississippi River (FMR) and Mississippi Park Connection to organize our BIPOC and youth tours because of their extensive experience, networks, and platforms for inviting BIPOC to events. FMR hosts a network of high school and middle school-aged students through their Environmental Stewardship Institute program. We also partnered with the Mississippi Park Connection and the Science Museum of Minnesota. Both organizations were hosting summer youth programs. These partnerships allowed us to develop tours that centered BIPOC and youth, who are usually excluded from these conversations, in a respectful and meaningful way.

During all our tours, we shared information about the history and function of the three upper Mississippi River locks and dams and the current disposition study. This helped participants imagine different futures for the Mississippi. This portion of each tour was important because it informed participants of the issues we eventually asked about in our survey at the end.

The demographic information we collected from community members who signed up for our tours showed us which communities we did and did not reach. We collected demographic information from tours between June 4th and July 27th, 2022, which included 9 public tours, 1 BIPOC-only tour, and 3 additional tours conducted by our partners at FMR for specific groups, including neighborhood associations from both sides of the river.

Figure 1. Participants engaging on our June 22nd boat tour and July 23rd bike tour.
Photo credits: David Wheaton (left) and Amber Wiedenhoeft (right)

Despite our very intentional efforts at reaching a more diverse audience for our tours, eighty percent of participants who provided demographic data identified as "Caucasian/White." Given the demographics of the Twin Cities, where 27% of the population identifies as people of color according to 2018 data, our tours lacked representative ethnic and racial diversity. This suggests the need for even deeper recruitment of participants. The age range of tour participants also favored an older demographic, with 48% of participants 56 years or older, 26.5% between 31 and 45 years, and 13.2% between ages 18 and 30. Over half of our participants identified as female (59.4%), with 39.6% male and 0.9% non-binary.

Our survey results also found that most tour participants frequently used the river. Sixty-three percent of participants said that they use the river at least several times a month and 28.6% use it several times a week. We know that those who are not river users have important points of view and should be part of the public engagement process. Finding those communities, and engaging with them intentionally, will require considerable effort.

Participants listed "hiking, running, and walking" (28.5%) and "biking" (18%) as the most common activities performed on or near the river. Other participants said they use the river for "rowing" (1.1%), "motorboating" (1.5%), and "fishing" (1.9%). These data suggest that our tours attracted individuals who wanted to join us to take part in the activities they regularly enjoy. To include different types of river-users, future tours could center on activities like fishing, birding, foraging, and rowing.

III. WHAT WE LEARNED

The surveys we conducted following each of our 13 focus group tours yielded important information about how to communicate with the public about locks and dams and disposition studies, and the most effective and inclusive ways to engage communities. We recognize that the Corps has the power to make important decisions about lock and dam infrastructure that will significantly impact surrounding communities for generations. It is vital that public engagement at this stage be as widespread and inclusive as possible.

a. Priming Engagement

For the public to meaningfully engage in disposition studies, it is important to provide foundational knowledge about the purpose of locks and dams, the Corps' current and potential future role in managing locks and dams, and other information that may impact public comments. Our survey results show that currently, accurate knowledge about the upper Mississippi locks and dams is not widespread among Twin Cities residents. Survey participants also shared what information they would find most helpful from the Corps in a disposition study public engagement process.

Each focus group tour included extensive background on the history and function of the locks and dams. After tours, we asked participants to name the authorized purpose of the infrastructure. Surveys show that members of the public continue to have uneven understandings of that purpose.

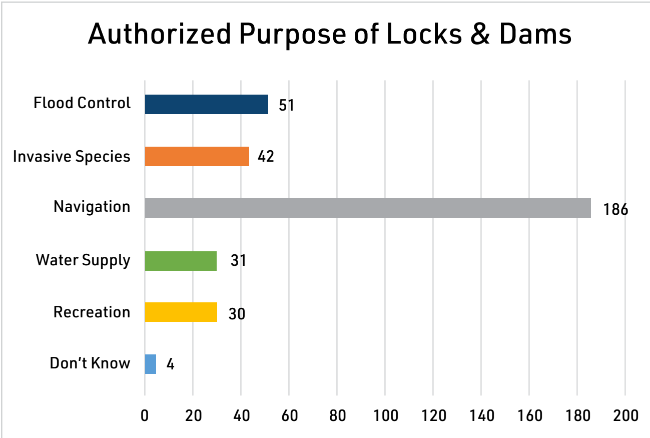
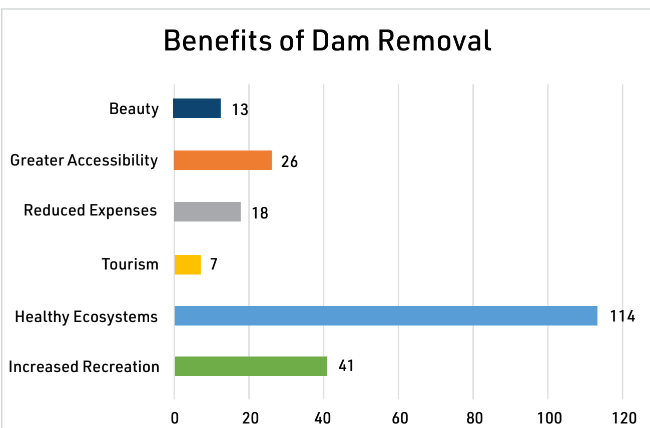


Figure 2. Authorized purpose of LSAF L & D and L & D No. 1 according to survey participants

Although we discussed that "navigation" was the original, congressionally authorized purpose on our tours, we were surprised that respondents did not select that answer. Forty-six percent of participants instead listed other purposes as primary, including flood control and water supply.



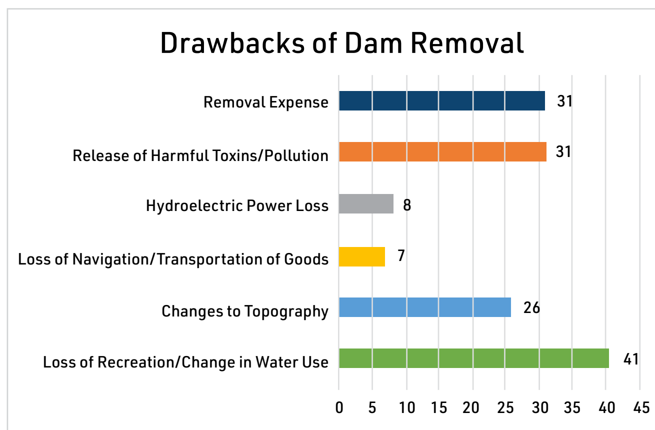


Figure 3. Benefits and Drawbacks of dam removal according to participants

The public's lack of understanding about the Upper Mississippi locks and dams may hinder their ability to meaningfully engage in disposition studies. This suggests a need for continued comprehensive public outreach and education.

The types of information survey participants thought would be useful to know prior to participating in a Corps disposition study provides guidance for topics the Corps can focus on in future research and community education. Of those surveyed, a large share of participants requested information about ecological impacts (26.4%) and about social and community impacts (21.3%). Tour participants also wanted to learn more about sediment toxicity, current and future costs of lock and dam maintenance, and the cost of dam removal.

Participants also told us what they thought the benefits and drawbacks to dam removal might be. This information can help the Corps understand what to prioritize in their public communication about lock and dam removal. As Figure 4 depicts, participants listed "Healthy Ecosystems," "Increased Recreation," and "Greater Accessibility" as a few of the benefits they saw for dam removal. They suggested "Loss of Recreation," "Release of Harmful Toxins," and "Removal Expense" as potential drawbacks to lock and dam removal.

While we see these as important topics to communicate to the public, we also found it notable that participants offered up a wider variety of drawbacks over benefits. In part, this might be explained by the fact that most of our participants were regular river users. As a result, it may be more difficult to imagine what a community may gain from removing the infrastructure, compared to the loss of what they know.

We suggest the Corps take steps to make it easier for the public to understand what a Mississippi River without these locks and dams would look like, including providing visual representations of future scenarios. The use of augmented and virtual reality could be particularly powerful in helping residents imagine a restored river.

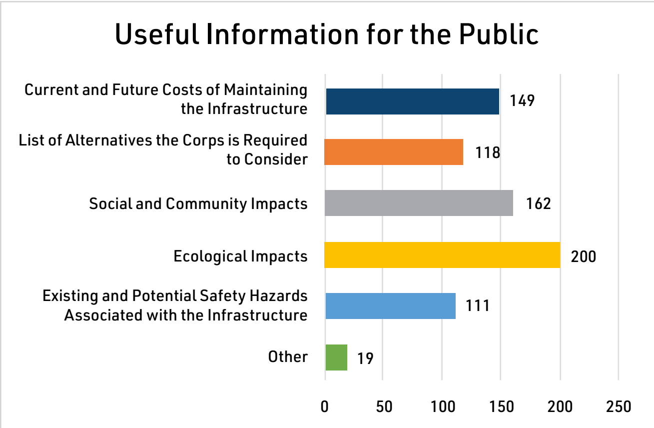


Figure 4. Information survey participants would find useful from the Corps

b. Engaging Diverse Communities

Engaging diverse communities in the Corps' disposition studies would ensure that Congress receives a recommendation that reflects input from those who will be impacted by their decisions. The Corps should take steps to reach a wider range of individuals, especially those who have historically been excluded from major decisions around infrastructure including BIPOC communities and youth.

Our research demonstrates that while the majority of our survey participants said they would participate in the current LSAF L&D and L&D 1 Disposition Study, only about half of the survey participants said that they knew about the study before engaging in our tours. Based on our team's previous research, we believe this percentage is relatively high. In summer 2021, our team collected 270 surveys at local river parks. When we asked this same question, we found that only 16.7% of people knew about the study. Our summer 2022 focus group participants likely belong to river-related groups that are following communications about the disposition study. The desire to participate, combined with the general lack of knowledge among most about the study process, suggests that the Corps' engagement methods should be more expansive.

Survey participants in our focus group tours suggested the best ways for the Corps to engage the public about the disposition study would be an online survey or an online public forum. The difference between the youth-only survey data and non-youth survey data is notable for this question. While only 7.5% of the non-youth-focused tour participants listed social media as the most convenient method for engagement, 16.1% of the youth we surveyed said that was the most convenient option.

Our survey results showed the tours we hosted helped people better understand the Mississippi and begin to imagine how the future river would look. The tours provided an opportunity to prime the public about the history of locks and dams and details about the disposition process. Many survey participants listed continued tours as a good way to engage the public.

While we recommend tours as an effective public engagement tool, each type of tour offers unique benefits. In summer 2022, we offered bike, boat, kayak, and walking tours. We found that walking tours were the most cost-effective and accessible. Although walking tours offer less interaction with lock and dam structures, they can reach the broadest audience with the fewest resources needed to organize them. Participants engaged the most with the river and infrastructure on boat and kayak tours, but they are the least cost-effective and require more planning and staff. By offering more walking tours, the Corps can educate the public about their work and receive feedback in an interactive environment.

Figure 5. Participants on our June 18th walking tour.
Photo credit Amber Wiedenhoeft

Surveys strongly emphasized the importance of including Indigenous people in the Corps' public engagement process because of their historical and cultural ties to the river. Responses included one individual who said the Corps should, "Center indigenous voices, put their desires first, and provide for the consideration of how to materially support their goals" and another who shared: "I want Indigenous folks to have the most say - they care for better standards of the land, and water, have ancestral ties and are owed some sort of reparations for their forcible exile/ expulsion from the place."

Participants in our survey provided potential ways to engage these communities. They suggested the Corps should connect with community leaders and specific groups (tribes and groups, NGOs, and colleges and schools) and outreach at community events, cultural centers, and community hubs. Many shared that they should engage with communities directly by hosting educational tours, canvassing at community events and centers, and meeting with community leaders.

The Corps should also consider how the timing and location of their events create barriers for participation. Offering meals, daycare, transportation and translation services might encourage wider attendance at in-person events. Many government agencies are now also providing an individual monetary incentive for participation to show that they respect the time commitment involved.

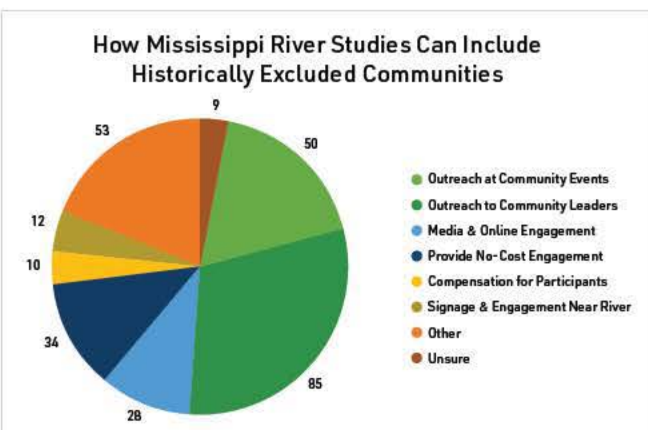


Figure 6. Increasing Outreach

IV. RECOMMENDATIONS

The focus group tours we hosted this summer, along with the post-tour surveys we collected, offer important insights into how the Corps can facilitate a more diverse and inclusive public engagement process. Below is a summary of our recommendations.

We recommend offering ***educational resources and public tours*** while collecting comments, and even after the comment period closes. Completion of the disposition study will take years, and we need to keep the public engaged and knowledgeable about the history and authorized purpose of the locks and dams. Continued access to the visitor centers and educational programs, like lectures, walking tours and public art, are vital toward this effort. If the Army Corps cannot staff these events, partnerships with the National Park Service and local nonprofit and educational groups might fill some gaps. We found walking tours inexpensive, accessible and able to accommodate large groups and provide close interaction with the river.

We encourage the Corps to present community members with ***visual representations*** of what a future Mississippi River might look like so they can better imagine the benefits and drawbacks of different scenarios. The National Parks Conservation Association has created a set of visualizations that could serve this initial purpose or serve as a baseline for additional images. Figure 7 includes one example. Additional images are available on the NPCA website at **www.npca.org/missriver**.

We recommend the Corps collect ***basic demographic information*** about who submits comments and attends public events. This information can be collected anonymously by providing those who submit comments a link to a survey. Demographic forms can also be provided when participants register at in-person or online events. Without this information, it is impossible to know who has and has not participated, and how to target future engagement.

We hope the Corps will prioritize ***intentional, inclusive, and diverse engagement opportunities,*** to collect additional information during the study process. It will be important to continue to build public interest and gather key stakeholder perspectives during the preparation of the study. This will ensure

Figure 7. Rendering of Lower St. Anthony Falls with lock and dam removed. Image credit LVBrown Studio

that there will be interest in the draft study when it is released. Our survey results show that each tour type we offered (i.e., walking, biking, kayaking, or boat) attracted individuals who were already committed or enjoyed that type of activity. Offering fishing or rowing events, for example, would engage new groups of people who have insight into those activities.

The Corps should provide ***online engagement*** opportunities. Survey results from both youth and adults suggested that many are interested in engaging with the Corps' study via online surveys or an online public forum. This would be particularly important as public health challenges are likely to surge in colder weather months, and outdoor conditions make travel to public events more challenging.

Finally, we urge the Corps to build partnerships with ***youth and youth-led organizations.*** We found that youth are deeply interested in thinking about the future river and have the capacity to participate and engage. While there may be limitations or concerns about working with minors, they are an important voice to include in the process. They will inherit the river.

Appendix A: 2022 Mississippi River Survey

This below two page survey was administered to participants at the completion of a tour.

2022 Mississippi River Survey Tour #:

The Army Corps of Engineers has completed their disposition study of Upper St. Anthony Falls. They will begin their study of Lower St. Anthony Falls Lock and Dam and Lock and Dam No. 1 next. This phase will consider dam removal. Your responses will shape future research and advocacy for the river. We will summarize survey results in a report to Minnesota political leaders and the Army Corps. All responses are anonymous.

1. How often do you visit the river?

- ☐ Every day
- ☐ Several times a week
- ☐ Several times a month
- ☐ Several times a year
- ☐ I rarely visit the river
- ☐ I do not live in the area

2. What activities do you regularly participate in at the river?

- ☐ Motorboating
- ☐ Rowing
- ☐ Kayaking, canoeing or paddleboarding
- ☐ Hiking, running, walking
- ☐ Biking
- ☐ Car and motorcycle touring
- ☐ Fishing
- ☐ Grilling, picnicking, celebrating
- ☐ Wildlife viewing
- ☐ Foraging, harvesting, collecting
- ☐ Playground use
- ☐ Other: ____________________

3. Based on your understanding, what is the primary purpose of the locks and dams?

- ☐ Flood control
- ☐ Recreation
- ☐ Water supply
- ☐ Navigation
- ☐ Invasive species control
- ☐ I don't know

4. Did you know about the Army Corps Mississippi disposition studies before today's presentation?

- ☐ Yes
- ☐ No

5. How likely are you to participate in the Army Corps disposition studies on the Mississippi?

- ☐ Very likely
- ☐ Somewhat likely
- ☐ Not likely

6. What type(s) of information would be most useful to you before you participate in an Army Corps disposition study in the future?

- ☐ Current and future costs of maintaining the infrastructure
- ☐ Existing and potential safety hazards associated with the infrastructure
- ☐ Ecological impacts
- ☐ Social and community impacts
- ☐ List of alternatives the Corps is required to consider
- ☐ Other: ____________________

7. What would be the most convenient way for you to share your opinion with the Army Corps in the future?

- ☐ In-person public forum
- ☐ Online public forum
- ☐ Written comment
- ☐ In-person survey
- ☐ Online survey
- ☐ Social media
- ☐ Other: ____________________

The next four questions refer to the future of Lower St. Anthony Falls and Lock and Dam No. 1 (Ford Dam)

8. What role should the Army Corps/federal government play in maintaining and operating the Lower St. Anthony Falls Lock and Dam and Lock and Dam No. 1 (Ford Dam)?

9. How can Mississippi River studies engage those who may have been historically excluded from political and infrastructural decision making?

10. What benefits or drawbacks do you think would result from dam removal in the Mississippi Gorge?

11. What do you wish for the Mississippi River?

Thank you for completing the survey.

Brookfield

Brookfield Renewable Energy Group
Twin Cities Hydro LLC
965 S. Mississippi River Blvd.
St. Paul, MN 55116
(651) 699-6277

October 5, 2017

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, D.C. 20426

Subject: **Twin Cities Hydroelectric Project (P-362)**
Statement of Generation in kWh for Hydropower Annual Charges for Licensed Hydroelectric Projects

Dear Secretary Bose:

Pursuant to 18 CFR §11.1(c)(4) of the Commission's regulations, Brookfield Renewable Energy Group on behalf of Twin Cities Hydro, LLC does hereby certify the following monthly generation at the Project during the period October 1, 2016 to September 30, 2017.

Month	**Generation (kWh)**
October 2016	10,175,547
November 2016	10,790,054
December 2016	9,111,321
January 2017	11,352,940
February 2017	10,018,715
March 2017	10,653,119
April 2017	10,018,838
May 2017	9,396,286
June 2017	10,471,727
July 2017	9,220,392
August 2017	7,541,124
September 2017	8,153,438
Fiscal Year Total	**116,903,501**

I verify that the information presented above is accurate and truthful.

Mike Summers
Technician

Jim Schwartz
Supervisor

Sworn to me and subscribed before me on this 27 day of October 2017.

Notary

(Seal)
JOHN J. DELUCA
NOTARY PUBLIC - MINNESOTA
My Commission Expires Jan. 31, 2019

Brookfield

Brookfield Renewable Energy Group
SAF Hydro LLC
1815 West River Parkway
Minneapolis, MN 55454

October 5, 2017

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, D.C. 20426

Subject: **SAF Hydroelectric, LLC (P-12451)**
Statement of Generation in kWh for Hydropower Annual Charges for Licensed Hydroelectric Projects

Dear Secretary Bose:

Pursuant to 18 CFR §11.1(c)(4) of the Commission's regulations, Brookfield Renewable Energy Group, on behalf of SAF Hydroelectric, LLC (SAF) does hereby certify the following monthly generation at the SAF Project during the period October 1, 2016 to September 30, 2017.

Generation (kWh)			
YR	**Mon**	**Gross**	**Net**
2016	October	4,039,319	3,973,597
2016	November	5,340,605	5,266,891
2016	December	2,132,912	2,048,838
2017	January	2,847,201	2,749,254
2017	February	1,912,746	1,842,475
2017	March	3,331,721	3,262,208
2017	April	4,439,534	4,366,308
2017	May	4,084,462	3,962,293
2017	June	4,242,755	4,192,600
2017	July	3,863,186	3,816,739
2017	August	4,956,502	4,892,307
2017	September	4,565,923	4,503,625
	Totals	**45,756,866**	**44,877,135**
	Station Load	**879,730**	
	Net Energy Delivered	**44,877,135**	

I verify that the information presented above is accurate and truthful.

Mike Summers
Technician

Jim Schwartz
Supervisor

Sworn to me and subscribed before me on this 27 day of October, 2017.

Notary

(Seal)

JOHN J. DELUCA
NOTARY PUBLIC - MINNESOTA
My Commission Expires Jan. 31, 2019

Journal of Geoscience and Environment Protection, 2021, 9, 62-78
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

The Socio-Economic Impacts of Aged-Dam Removal: A Review

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How to cite this paper: Perera, D., & North, T. (2021). The Socio-Economic Impacts of Aged-Dam Removal: A Review. *Journal of Geoscience and Environment Protection, 9,* 62-78.
https://doi.org/10.4236/gep.2021.910005

Received: September 1, 2021
Accepted: October 19, 2021
Published: October 22, 2021

Abstract

Water storage dams worldwide are ageing, and many will reach the end of their designed lifespan by the middle of the 21st century. Some of these dams will likely need to be removed. While dam construction impacts have been widely discussed, dam removal impacts on society and the economy need to be synthesized and considered in the ageing dams' decision-making process. This paper summarizes dam removal impacts on the local economy and industry, culture, history and heritage, property value, recreation, aesthetics, and disaster avoidance from identified studies worldwide. It demonstrates that these impacts may vary depending on geography and between developed and developing countries. It concludes that dam removal should consider the cost, environmental, and the socio-economic impacts while including all stakeholders who could be positively and negatively impacted by dam removal.

Keywords

Dam Ageing, Dam Removal, Large Dams, Social Impacts, Economic Impacts

1. Introduction

Water storage infrastructure, particularly large dams, has traditionally been used to regulate river flows globally, benefiting countries by fulfilling water and energy needs. By 2020, the global large dam count was over 58,000 (>15 m height; or 5 - 15 m height and impounding > 3 million m^3 of storage as defined by the International Commission on Large Dams—ICOLD—https://www.icold-cigb.org/GB/icold/icold.asp). Cumulatively, dams store approximately 16% of global surface water resources (Hanasaki et al., 2006). Around 93% of the world's large dams are built in 25 countries, with China and the USA leading with the greatest number of large dams (23,841 & 9263, respectively). By continent, Asia has the majority (~55%) of the large dams globally, while Africa has the fewest (~2000; ICOLD WRD, 2020).

The main dam functions are irrigation, hydropower, water supply, and flood control, while other functions include recreation, navigation, and fish farming (ICOLD WRD, 2020). Irrigated agriculture ensured largely by dams, contributes about 40% of world agricultural production (Shah & Kumar, 2008), while hydropower dams generate around 20% of global electricity production (IHA, 2020). Dams store large volumes of water during extreme rainfall events, reducing the likelihood of downstream flood disasters (Berga, 2009). Additionally, most of the world's urban, agricultural, and industrial regions' water security is sustained by these large storages (Vörösmarty et al., 2010).

Building of large dams was upsurged in the mid-20th century, and its peak was in 1960-1980s, and declined afterward (Perera et al., 2021) due to a range of factors, including environmental and social costs, lack of transparency, low stakeholder participation, and reduced finances and investments (Grigg, 2019). Like any infrastructure, large dams are constructed with a design life, and as they age, they become more expensive to repair and maintain and increasingly vulnerable to failure. Ageing is understood to be the gradual deterioration beyond the initial five years of operation (Zamarrón-Mieza et al., 2017). In general, dams constructed between 1930-1970 have an average design life ranging from 50 to 100 years (Mahmood, 1987; Ho et al., 2017). Consequently, many large dams worldwide have reached or are approaching the 50 years mark, which may be seen as the lower boundary of their design lifespan. Regular inspection and repair with a sound management plan can significantly extend a dam's life span, yet many ageing dams will likely be considered for re-operation or complete removal. Dam removal, and particularly large dam removal, is not yet a common practice nor an easy process. There are many factors, including the cost of repair, cost of removal, socio-economic impacts, public safety, environmental impacts, and government policies for water, energy, and food production, amongst others, that need to be considered to make informed decisions on dam removal. While the cost of removal, loss of dam function, and environmental impacts are key considerations in the removal process, there is a range of important socio-economic impacts that are important to distill from global emerging practices and should be considered as well. This paper aims to identify such socio-economic impacts of dam removal as reported in the global literature.

2. Dam Ageing and Removal: A Global Snapshot

Dam ageing is gradually appearing as a global development challenge experienced by many countries. Perera et al. (2021) carried out the first global synthesis of ageing water storage infrastructure, illustrating the magnitude of the problem by major geographical region, country, and dam function, quantifying emerging trends of dam removal, and identifying the key considerations for decision-making on aged-dam removal. **Figure 1** provides a snapshot of the current knowledge of dam age by major region and dam function.

In North America and Asia, ~16,000 large dams are between 50 and 100 years old, and over 2000 dams were constructed over a century ago. In Europe, ~10% of large dams are over 100 years old, while in the United Kingdom, large dams' average age is greater than 100 years (Perera et al., 2021). In the USA, over 85% of dams exceed their design life expectancy (FEMA, 1999). Dam ageing poses a threat poses a threat to public safety and has potentially dramatic impacts on both the economy and the environment.

The risks linked with ageing large dams are extreme and can result in loss of life, property, and livelihoods. For example, in March 2009 the Situ Gintung Dam failed in Indonesia's Tangerang District, killing over 100 individuals. Built-in 1933, little maintenance had been done for 76 years (USBR, 2015). Unfortunately, this is not an isolated case and ageing dam failures threaten lives across the globe (e.g., Ivanovo Dam, 2012; Kantale Dam, 1986; Kelly Barnes Dam, 1977; **Table 1**). Over 30,000 dams in China are ageing and at high risk of failure (Yang et al., 2011), while in the USA approximately 15% of dams are considered a high hazard (Ho et al., 2017). By 2050, the predicted world total population will be nearly 10 billion (UN Water, 2019). The majority of the population will reside downstream of large dams (Ferre et al., 2014), primarily constructed in the 20th century or the early 21st century. Therefore, informed decision-making regarding ageing dams will be paramount to protect growing downstream communities. The impacts of dam ageing can be local, national, or international (e.g., dams in transboundary rivers). The unique characteristics of each dam (location, age, function, capacity, etc.) make the ageing issue very diverse. Thus, the problems arising from ageing dams will manifest themselves in different ways and at different times. Additionally, other risk factors such as climate change-induced extreme events, sedimentation, environmental impacts, and security threats will lead stakeholders to decide on each dam's fate in the 21st century.

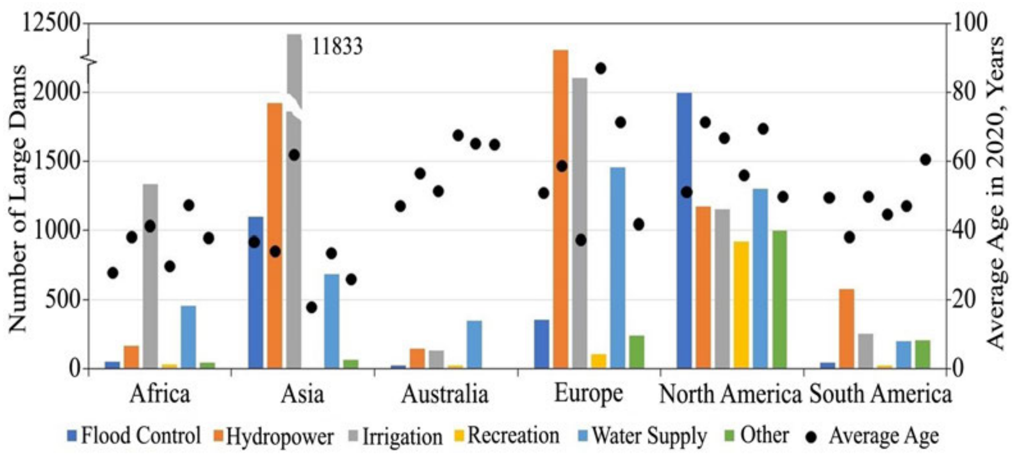

Figure 1. Average age (circles) and number of large dams (bars) in main geographic regions by their functions (graph source: Perera et al., 2021 based on ICOLD data).

Table 1. Examples of dam failures from ageing infrastructure.

Dam Name	Country	Age	Year of Failure	Fatalities	Reason for Failure
Brumadinho Dam (Zimmermann, 2019)	Brazil	43	2019	270	Structural flaws
Panjshir Valley Dam (Associated Press, 2018)	Afghanistan	>50	2018	10	Structural flaws, heavy rain
Ivanovo Dam (Cooper & Gleeson, 2012)	Bulgaria	75	2012	8	Structural flaws, heavy snowmelt
Kantale Dam (Jayathilaka & Munasinghe, 2014)	Sri Lanka	>100	1986	180	Structural flaws, poor maintenance
Kelly Barnes Dam (USBR, 2015)	USA	78	1977	36	Elevated reservoir levels

Dam managers can consider three potential solutions to manage ageing dams. The first is repair, which involves restoring dam function and safety to remain operational. Re-operationalization is another option that modifies the original dam operation to recover social and ecological benefits by implementing integrative management approaches (Watts et al., 2011). This could include targeting water releases from the reservoir to mimic the inflow rate, creating plans to minimize consumptive water losses from the reservoir, amongst other approaches, and can incorporate multiple dams (Watts et al., 2011). The third solution, dam removal, includes dismantling the dam completely and allowing free river flow. Thus far, most removals have occurred at small dams (<5 m) in the USA and Europe, and removals of large dams are still limited (Perera et al., 2021). Among the three available solutions, selecting the best option is case-specific and requires an in-depth decision-making process covering technical, social, and economic elements related to the dam.

In recent years, dam removal has gained attention as a potential solution to managing ageing infrastructure while also repairing the environmental integrity of riverine ecosystems. While dam repair preserves dam function, maintenance is often expensive and ongoing and can be 10 - 30 times costlier than removal (Grabowski et al., 2018). Similarly, while re-operationalization has been demonstrated to improve the ecological (Bednarek & Hart, 2005) and social (Vonk et al., 2014) impacts of dams, optimizing dam operations is complex and many dams no longer provide the benefits that once justified their development (Labadie, 2004). Alternatively, dam removal may involve the full or partial removal of dam infrastructure. Removal may be a feasible alternative if economic, social, and practical limitations prevent the dam from being renovated or its expected function is now outdated (Doyle et al., 2003). Removal allows rivers to flow freely again, benefitting migratory fish and aquatic ecosystems (Grant & Lewis, 2015). However, dam removal can have consequences as well. Functionally, there may be a loss of services provided by the dam, such as hydropower generation, irrigation, or flood control, which may need to be replaced or recovered. This may not be advantageous for some countries, communities, and individuals that rely on dam services. Environmentally, sediments in the upstream reservoir can adsorb contaminants which may be released when the dam is removed (Grant, 2001). In these cases, repair or re-operationalization is likely a more suitable option to maintain safe dam functioning. Additionally, the lack of dam removal policies means that removal is not regulated (Doyle et al., 2003). Given this dichotomy, understanding the socio-economic impacts of dam removal remains a critical gap in ensuring the proper management of ageing infrastructure (Bellmore et al., 2017).

3. Socio-Economic Impacts of Dam Removal

3.1. Local Economy and Industry

Dam removal is becoming an accepted approach to mitigate the risks associated with ageing infrastructure. After dam removal, a shift in the industry is expected as the immediate environment and resources change. Dam removal affects the industries such as fisheries, agriculture, tourism, and hydropower and impacts livelihoods and employment opportunities.

Fisheries commonly contribute to regional economies across the globe, and particularly for low-income individuals, fish represents a major source of protein (Kent, 1997). Rivers are rarely dammed for fish harvesting as the only purpose; however, in some cases, the secondary importance of the fishery may exceed that of the reservoir's primary function (Fernando, 1980). In developed countries, reservoir fisheries often serve recreational needs, while in developing countries, reservoir fisheries provide a critical source of protein and employment often in rural communities (Sugunan, 1995). In addition, high yields in reservoirs are often a result of stocking programs where exotic fish species are introduced (Jackson & Marmulla, 2001). Overall, reservoir ecosystems are repeatedly stressed due to the high levels of nutrient input and unidirectional flow and are not conducive to support fish populations. As a result, damming rivers may cause significant losses of riverine fish harvests (Jackson & Marmulla, 2001). Therefore, dam removal may be beneficial to increase fishery yields.

In the USA, restoring rivers has significantly improved the quality and quantity of fish habitat and salmon migration which is both ecologically and economically beneficial (Witze, 2014). Mapes (2016) mentioned that during the first season after the Elwha Dam was removed in the USA, over 4000 spawning Chinook were observed. Several other studies conducted in the USA point to an increase in fish population after dam removal (e.g., Hardiman & Allen, 2015; Allen et al., 2016). Likewise, after the removal of the Arase Dam in Japan, fishermen reported increased seaweed cultivation and shrimp harvesting and the return of sweetfish, a highly sought-after species (Ohno, 2019). In Sweden, after removing the Storsjö-Kapell dam in the Storsjö fisheries conservation area, fishermen expected to double the value of large fish and quadruple the fish stocks (Lejon et al., 2009). Since dam removal restores both terrestrial and aquatic ecological functioning, it is likely that river fisheries are more sustainable and will provide higher yields than reservoir fisheries. However, this may not be the case in more arid regions.

Dam removal can be beneficial or disastrous to the agricultural sector. Globally, nearly 50% of single-use dams were built to provide water for irrigation, and these dams supply water to over 1 million km^2 of land (ICOLD WRD, 2020). The dependency on dams for irrigation is dictated primarily by climatic conditions. In temperate zones, agriculture can be conducted without a water management system, while in arid or semi-arid zones, agriculture without irrigation can be impossible (Schultz, 2002). Therefore, the impact of dam removal on agricultural production will be primarily influenced by the regional climate and water availability. Particularly for countries with emerging economies, dams, irrigation systems, and hydropower play a critical role in fighting against poverty (Barker, 2004). By increasing water availability in arid regions, more irrigable land will be used for food production, improving rural livelihoods (Hasnip et al., 2001). For example, in India, water availability for irrigation significantly reduces poverty in rural areas (Lipton & Litchfield, 2003). However, although poverty is reduced downstream of dams providing irrigation, poverty may be increased in the dam's immediate vicinity (Duflo & Pande, 2007). Therefore, in regions that rely on dams to supply water for irrigation, removal could have detrimental consequences to the surrounding community's livelihoods. The extent of these impacts likely varies with the vicinity of the dam.

In many regions, dam removal may benefit individuals who previously relied on the reservoir footprint for their livelihoods, such as pastoral communities or those who partake in subsistence farming. For example, after the Senegal River was dammed in the 1980s, over 300,000 individuals lost their traditional flood-recession farming land and practices (Adams, 2000). If the dam was removed, these individuals could reclaim their land and traditions. In Alberta, Canada, the construction of the Bighorn Dam on the North Saskatchewan River in the 1970s flooded the entire land claim of the Bighorn First Nation, which prevented hunting, guiding, and fur trapping and forced 95% of the population onto welfare (Notzke, 1994).

In addition to agriculture and fisheries, tourism is another sector that can be stimulated by dam removal in a local/regional economy. For example, after the Arase Dam removal in Japan, the village saw a boom in local job opportunities. Riverboat and rafting companies began offering tours along the river, sweetfish restaurants opened, and fishing weirs were installed as tourist attractions (Ohno, 2019). The increase in tourism and the accompanying infrastructure led to the revitalization of the Sakamoto Village (Ohno, 2019). Likewise, a cost-benefit analysis regarding the removal of dams along the Snake River, USA, demonstrated that after removal, the largest long-term increase in employment would occur because of increased tourism (Whitelaw & Macmullan, 2002). However, these dams were never removed.

Twenty percent of the world's electricity is generated by hydropower, the primary renewable energy source (WWAP, 2017). Although access to electricity has increased from 71% in 1990 to 87% in 2016, nearly one billion people still lack access to electricity, predominately in Africa and South Asia (Ritchie & Roser, 2020). According to the National Inventory of Dams (USA), hydroelectric dams are more often removed than dams that provide other functions, primarily due to relicensing requirements (Grabowski et al., 2018). Additionally, some facilities may be rendered obsolete when regional power grids can use more efficient electricity sources (Baish et al., 2002). For example, the Woolen Mills dam in Wisconsin was built in 1919 for hydroelectricity generation but fell out of use by the 1950s. After showing structural flaws, it was removed in 1988 at 38 times cheaper than the replacement cost (Baish et al., 2002). In France, two dams along the Sélune River were considered for removal in 2009. Opponents of removal argued that the dams provided green energy (27 GWh/year) to help meet France's renewable energy targets. In contrast, the proponents argued that the two dams provided merely 0.04% of France's total hydropower production and significantly less electricity than the nuclear power generation station nearby (Germaine & Lespez, 2017). The dams were not removed.

These cases reflect two contrasting decisions on hydroelectric dam removal. However, each was contentious and had stakeholders that represented both sides of the debate. It is important to note that both cases above originate from developed countries where access to electricity is nearly universal. In countries where individuals have limited access to electricity in their homes and workplaces, hydropower dams may be integral to closing the electricity access gap and improving livelihoods. Therefore, in developing regions that rely significantly on hydroelectricity for their power supply, dam removal may have far-reaching negative consequences and may not be a feasible alternative to overcome the issue of ageing dams. Case studies that explicitly support this statement are, however, currently lacking.

3.2. Culture, History, and Heritage

Regional heritage and cultural history can be impacted by removing a dam in that particular region. Dams may still hold value to residents because of their longstanding history and ties to past industries even though they no longer serve their intended function. In New England, USA, dams are often associated with old mill sites (Lenhart, 2003), while in Sweden, many dams historically served industrial communities, mills, and factories (Lejon et al., 2009). These dams are considered essential aspects of the environment. In fact, many old mill sites in New England were revitalized to preserve their historical importance to the economy in the 19th century (Kotval & Mullin, 2009).

The commemoration of a dam's history may be essential to maintain the dam location's historical and cultural integrity post-removal. The inclusion of museums, plaques, or commemorative statues may be used to honor the history of a since-removed dam. In New Hampshire, USA, the timber cribbed McGoldrick

Dam built in the 1850s was removed on the Ashuelot River in 2001 for ecological restoration purposes (NHDES, 2017). The dam's original use was rendered obsolete. However, the dam retained historical value as it allowed the nearby town to expand from an agricultural village to a manufacturing town in the 1800s. The State Historical Societies and State Historic Preservation Offices were involved in taking photographs to create a historical inventory. Then, plaques and interpretive signs were installed to commemorate the dam and educate the public on the river's rich history (Goddard-Bowman, 2014). The effort to create a historical inventory that can be shared with the public can lessen the negative impacts of dam removal on cultural history and heritage.

Conversely, dam removal may turn previously impacted areas to their original state. In North America, many Indigenous communities have deep spiritual ties to their land, rivers, and the resources they support. Many dams have negatively impacted these resources and were installed with little regard for and input from Indigenous communities (Guarino, 2013). For example, when the Glen Canyon Dam was built in Arizona, USA, hundreds of archaeological sites important to the Navajo Nation were lost (Baish et al., 2002). Similarly, in New Brunswick, Canada, the decision to repair an ageing dam disappointed Kingsclear First Nation, whose land rights, fishing grounds, and spiritual connection to the river were all diminished when the dam was built (White, 2016). The Mactaquac dam was estimated to cost CAD $3.6 billion and CAD $4.3 billion for repair and removal, respectively (White, 2016). Dam removal may allow the renewal of sacred land and increase the cultural and historical value in an area.

3.3. Property Value

A common fear of dam removal is the impact it will have on property value. Individuals living along reservoirs tend to believe that lakefront properties are more attractive to buyers in the real estate market than riverfront properties (Born et al., 1998; Bohlen & Lewis, 2009; Nicholls & Crompton, 2017). However, reports indicate that the river frontage is as much if not more valuable than the original lake frontage (Haberman, 1995). After the removal of a small dam in Wisconsin, USA, there was no significant change in property value when the residence was on the shore of the impoundment than along the free-flowing river. Additionally, housing value in the vicinity of the free-flowing river was higher than properties in the vicinity of the impoundment (Provencher et al., 2008). However, this study looked only at small dams where recreational value was limited. In Maine, USA, the removal of a large dam increased local property value, in part because of dam removal itself, but also due to improving water quality after dam removal (Lewis et al., 2008). Overall, the literature suggests that property values are unlikely to drop and may even improve when dams are removed, and rivers can flow naturally.

3.4. Recreation

Over 4000 dams globally registered in the ICOLD database serve recreational purposes (ICOLD WRD, 2020). Dam reservoirs may be used for watersports, fishing, swimming, camping, and hunting. Recreation is not a strictly decisive factor in dam building or removal of a dam; however, recreation often becomes an important secondary factor (Pohl, 2002). In addition, recreation attached to a dam is significantly weighted by the public as leisure activities (Wyrick et al., 2009). Therefore, dam removal is two-fold in recreational activities that can account for either gains or losses.

The recreational value of dams is challenging to quantify, as is after removal. Born et al. (1998) examined 30 small dams in Wisconsin, USA, and the public's opinion on their removal. They found that the main perceived deterrent of dam removal was the loss of recreation. However, those who supported dam removal cited an increase in recreation as one of their main arguments (Born et al., 1998). In addition, in the Pacific Northwest of the USA, removing four dams along the Snake River was projected to increase the river's recreational value by six to ten times (Loomis, 2002). Dam removal will eliminate the reservoir, which may decrease opportunities for watersports, boating, and swimming, but conversely, it may also improve recreational opportunities. After a dam is removed and the natural shoreline begins to re-establish, other recreational opportunities could be created, including whitewater rafting, canoeing, and kayaking (Loomis & Walsh, 1997). Boat launches, recreational trails, and greenspace are also essential to facilitate recreation after dam removal. Given this dichotomy, it is vital to work with community members to optimize recreational uses after dam removal, and by implementing innovative alternatives, the loss of recreation from dam removal can be rectified.

3.5. Aesthetics

When considering dam removal, engineers and policymakers prioritize safety and economics while residents tend to prioritize aesthetics and recreation (Wyrick et al., 2009). As an essential group in the stakeholders of dam removal projects, considerations of community's perspectives are crucial to mitigate the potential loss of aesthetics after dam removal. In 2009, 17 dams in Sweden were in consideration for removal (Lejon et al., 2009). For stakeholders, aesthetic reasons against dam removal included muddy stream banks, loss of reflection ponds, and changing views. Proponents of dam removal stated the aesthetic value of free-flowing water (Jørgensen & Renöfält, 2013). Aesthetics is an exceptionally subjective and polarizing topic. The preference for still or running water is the central anchoring point for both sides of the dam removal controversy (Jørgensen & Renöfält, 2013). Likewise, one of a misconception that prevails is that dam removal will damage the scenery by resulting muddy, waterlogged, and unpleasant reservoir footprint (Sarakinos & Johnson, 2003). While this may be true initially, studies post-removal indicate that vegetation grows back rapidly, and bare sediment is rare as soon as one year after removal (Lejon et al., 2009). Additionally, the nutrient-rich sediment and access to sunlight may improve growing conditions (Hörnström, 2009). In many cases, dam removal enhances aesthetics by increasing wildlife and water quality. Creating green space and riverfront revitalization during or after the removal processes can improve aesthetics and appease residents and users (Baish et al., 2002).

3.6. Disaster Avoidance

Even when structurally sound, large dams are considered "high hazard" forms of infrastructure because of the possible loss of human life resulting from failure (USBR, 2015). Urban development downstream of dams is persistent and thus elevates the magnitude of dam failure. Dam failures may result from seepage, cracking, overtopping or structural failure. Several failures have occurred in dams over 50 years old (Foster et al., 2000; Zhang et al., 2009). When combined with poor maintenance and infrequent inspection, older dams present a high risk to public safety. Dam failure can lead to extensive loss of life and property damage. For example, 1 billion USD in property losses were estimated as a result of the Teton Dam collapse in Idaho, USA. A small dam failure in West Virginia, USA, took the lives of 125 individuals (Ellingwood et al., 1993). Removing ageing dams that are vulnerable to failure is an effective and proactive way to prevent loss of life and to protect property.

3.7. Socio-Economic Impacts of Dam Removal in Different Settings

The extent of the impacts of dam removal may vary based on geographic location and socio-economic conditions. In developed nations where water availability is high, many ageing dams have been rendered obsolete. In these cases, removal may be the ideal choice to manage ageing infrastructure because of the cost-benefit and positive ecological impacts of regaining a free-flowing river. In countries such as the USA and Sweden, the primary concern for residents when considering dam removal is a loss of recreation, aesthetics, and property value. These impacts can largely be mitigated through education, commemoration, and the creation of greenspace surrounding the reservoir. In fact, these variables may increase after dam removal because of improved water quality and ecosystem health. However, dams are critical infrastructure for low-income countries for water supply, irrigation, and electricity generation. In these cases, dam removal may be impractical and not a viable option. Thus, implementing one-size-fits-all criteria to assess and prioritize dam removal projects in the global context is at least useless, and may be dangerous. Setting dam removal in the correct social, economic, and geographic context is critical to ensure sustainable development.

Climate projections estimate that global mean temperature will increase if greenhouse gas emissions continue at their current rate (Collins et al., 2013). However, the increase in temperature will not be uniform (Collins et al., 2013) nor will it impact all regions equally (Mendelsohn et al., 2006). Developing nations and those located in the global south are likely to suffer the most from a warming climate (Mendelsohn et al., 2006). Additionally, global water use has increased six-fold in the past century (Wada et al., 2016). As the climate becomes hotter and drier, increased pressure will be placed on governments and community leaders to supply water to growing populations. The global population is expected to increase to between 9.4 and 10 billion by 2050, with most of the growth occurring in Africa and Asia (UN Water, 2019). Therefore, innovative technologies and collaborative efforts will be required to provide safe, sufficient water to regions that are particularly vulnerable to climate change.

For the successful management of ageing dams, the dam removal process should be incorporated as a critical component in a dam's planning phase. The process should include all stakeholders who are positively and negatively impacted by an existing dam and consist of up-and-down-stream communities, engineers, dam managers, and policymakers. Additional considerations should consist of steps to rectify dam removal impacts, replace the existing benefits of a dam, and synchronize the environment and the communities with the dam removal. These should be considered critical in developing a framework for dam removal. Furthermore, scenario analysis for the risk and costs involved in a dam removal process should be required. Among others, Baecher et al., 1980; Boardman et al., 1996; Whitelaw & Macmullan, 2002; Headwaters Economics, 2016; have discussed various concepts and methodologies of cost-benefit analysis for dam-removal based on case studies of various dam removal projects.

4. Conclusion

Dams have traditionally been used to secure water and electricity needs and provide a wealth of benefits, including irrigation, water supply, flood control, and recreation. However, thousands of large dams built in the middle of the previous century have already or will exceed their intended lifespan. As a result, their structural integrity or functional ability may become sub-optimal, and they will incur more significant maintenance costs while posing threats to the environment and human safety. Such issues lead to questions of dam repair, removal, or re-operationalization. Dam removal is a relatively recent phenomenon and has become common in the USA and Europe. Socio-economically, dam removal impacts aesthetic, recreational, historical, and property values and affects jobs and livelihoods. Developing and developed countries perceive dam removal in different contexts due to their technical and economic strengths. Therefore, it is unlikely to define unique combinations of socio-economic benefits in developing and developed worlds. Decisions regarding dam removal should incorporate social, economic, and geographic considerations in regionally explicit contexts. Overall, dam removal should be seen as equally important as dam building in the overall planning process on water storage infrastructure developments.

Acknowledgements

This research is supported by the funds received by UNU-INWEH through the long-term agreement with Global Affairs Canada. The year 2021 marks the 25-th anniversary of UNU-INWEH. Thanks are due to Dr. Vladimir Smakhtin (UNU-

INWEH) for the constructive comments on the paper.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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THE ECONOMIC IMPACTS

OF

ECOLOGICAL RESTORATION IN MASSACHUSETTS

MASSACHUSETTS DEPARTMENT OF FISH AND GAME
Division *of* Ecological Restoration

September 2011

MASSACHUSETTS DEPARTMENT OF FISH AND GAME

Division *of* Ecological Restoration

Tim Purinton, *Director*

Deval Patrick
Governor
Timothy P. Murray
Lieutenant Governor
Richard K. Sullivan, Jr.
Secretary
Mary B. Griffin
Commissioner

The Division of Ecological Restoration (DER) was established in July of 2009 with a merger of the Department of Fish & Game's Riverways Program and the Wetlands Restoration Program of the Office of Coastal Zone Management.

DER pursues its mission "to restore and protect the Commonwealth's rivers, wetlands and watersheds for the benefit of people and the environment" by working with many different partners on projects that produce the greatest ecological return for the investment while supporting local jobs and the regional economy.

As a result of this approach:

• DER leverages state dollars at a ratio of 1 to 12 (state to non-state funding) and attracts millions of competitive federal dollars annually into the Massachusetts economy.

• Our projects produce an average employment demand of 12.5 jobs and $1,750,000 in total economic output from each $1 million spent, contributing to a growing "restoration economy" in Massachusetts.

• Our ecological restoration projects help support a number of economic sectors, including design and engineering, construction, wholesale construction materials, nursery products, and non-profit science.

• Because of this diversity of contributing sectors and the non-export nature of the projects, the "ripple effects" from a dollar spent on ecological restoration travel widely through the Massachusetts economy.

• While not accounted for in this study, the ecosystem services values produced by our partner-based projects (e.g. water quality improvement, flood damage reduction, and increased biodiversity) generate substantial, recurring economic benefits.

• Restoration projects generate total economic outputs equal to or greater than other types of capital projects such as road and bridge construction and repair, replacement of water infrastructure, etc.

Learn more about us at:

http://www.mass.gov/dfwele/der/index.htm

Follow us on Twitter: twitter.com/MassEcoRestore

Economic Impacts of Massachusetts Ecological Restoration Projects

Executive Summary

Industrial Economics, Incorporated (IEc) analyzed four ongoing or completed restoration projects, using the IMPLAN regional economic impact model, as a means to help the Massachusetts Department of Fish and Game, Division on Ecological Restoration (DER) gain an initial sense of the direct and indirect effects of their activities on a "per restoration dollar" basis. The four projects are:

- **Broad Meadows Restoration** (Quincy), comprising excavation of 60 acres of dredge spoils and re-creation of a salt marsh and tidal creek system.
- **Eel River Headwaters Restoration** (Plymouth), comprising removal of six dams, replacement of two culverts, and naturalization 40 acres of wetland in a former cranberry bog.
- **Stony Brook Restoration** (Brewster), comprising removal of a culvert from a former tidal wetland to restore fish passage and the natural tidal regime.
- **North Hoosic River Restoration** (Clarksburg), comprising removal of a dam to provide upstream flood mitigation benefits and to restore ecological functions and values.

DER provided IEc with the detailed project cost information required to run the IMPLAN model. Based on available information, IEc estimated the share of each cost item that would be considered a "Massachusetts expenditure" in order to isolate in-state (rather than more broadly regional) impacts. These in-state project costs ranged from approximately $630,000 (North Hoosic River) to approximately $5.4 million (Broad Meadows). IEc also tested the sensitivity of the results to the assumptions regarding in-state and out-of-state costs by running IMPLAN a second time and assuming all expenditures occur in Massachusetts.[1]

The modeling results indicate total employment effects ranging from 7.6 to 70 "jobs." Note that the employment effect is not solely the creation of "new" jobs, but rather the creation of employment demand (in "full-time equivalent" units) that may or may not result in a permanent job. The total employment effect includes direct effects (employment that results from a project itself), indirect effects (employment related to the providers of goods and services to the project), and induced effects (employment related to the expenditure of income from direct and indirect employment). In each case, IEc estimates that direct employment accounts for approximately 60 percent of the total employment effect. Per million dollars of restoration cost, these four projects are estimated to result in an employment demand of 10-13 full-time equivalent jobs. The sensitivity analysis indicated an average increase in the total employment effect of approximately 22 percent when individual expenditures were all categorized as in-state.

A second measure of economic activity is total economic output resulting from the "multiplier" effect of restoration expenditures. As with employment, total output is the sum of the output attributable to direct,

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[1] Since all expenditures associated with the Broad Meadows project were initially assumed to be in-state, the estimated economic impact of this project did not change.

indirect, and induced effects. IEc estimates total output associated with these four projects to range from approximately $1.4 million to approximately $1.8 million per million dollars of restoration cost. The change in estimated output when all project expenditures were assumed to occur in-state was an average increase of 23 percent.

One of the key limitations of this analysis is its focus (necessitated by data limitations) on the economic impacts of the short-term, construction phases of these projects. Over the longer term, the ecological benefits of the restoration projects are likely to produce additional, positive economic effects, possibly including, but not limited to, those related to increased use of the project site for recreational purposes or to changes in adjacent or nearby property values.[2]

IEc supplemented its modeling of Massachusetts projects by identifying, reviewing, and summarizing published studies that also describe estimates of employment demand and total output attributable to restoration activities. IEc identified four relevant studies, three describing activity in the western United States (California, Oregon, and Montana) and one focused on Massachusetts. The three studies in western states describe total employment effects ranging from approximately 15 to approximately 30 jobs per million dollars of project cost, and total economic output per million dollars ranging from approximately $2 million to approximately $2.6 million. Geographic, activity type, and possibly scale differences likely limit the direct comparability of these studies to the results of the IEc analyses, but they do provide an indication that the Massachusetts results are a good first approximation of economic impacts. The Massachusetts-focused paper, which suggests an employment effect of approximately 40 jobs per million dollars of investment in the “reforestation, land and watershed restoration, and sustainable forest management” sector further supports this preliminary conclusion.

The limited number of projects included in the IEc analysis makes it difficult to draw general conclusions about the economic impacts of these types of activities on a per-dollar basis. However, the consistency of the results across projects, and types, suggests that relatively limited additional analysis could provide a sufficient basis for establishing economic impact “rules of thumb,” at least for short-term effects. A larger data collection and analysis effort would be needed to address the (potentially significant) economic impacts that projects like these would be expected to generate over the longer term.

[2] Related to the assessment of long-term benefits, IEc also produced a white paper for DER describing emergent tools and techniques for the quantification and monetization of a variety of “ecosystem services” that restored sites might be expected to provide, such as flood mitigation or carbon sequestration.

IEc

Economic Impacts of Massachusetts Ecological Restoration Projects

Final Briefing

Prepared for
Massachusetts Department of Fish & Game
Division of Ecological Restoration

30 June 2011

COMMONWEALTH OF MASSACHUSETTS
Division *of* Ecological Restoration

INDUSTRIAL ECONOMICS, INCORPORATED

Study objectives

Final

- Provide the Massachusetts Division of Ecological Restoration (MA DER) with an initial sense of the direct and indirect economic “returns” generated by representative restoration projects in Massachusetts.
    - Regional economic impact modeling of four projects.
    - Comparison to results of similar studies, as documented in the published or grey literature.
- Provide a white paper on the concept of ecosystem service valuation and its application in the context of the state’s restoration activities.

Methodology

Final

- We examine regional economic benefits associated with increased economic activity in Massachusetts resulting from restoration projects.
- We use IMPLAN Version 3.0, with the most recent available data (2009) for MA.
- Project cost details were provided by MA DER.

Methodology (continued)

Final

- Impacts can be observed in two phases:
  - Short term effects: These are benefits associated with increased demand for employment, materials, and services in Massachusetts during the Construction/Installation Phase of a project. Examples include: construction labor, materials costs, engineering time, permitting activities.
  - Long-term effects: These are benefits associated with the Operational Phase of a project. These may include, for example, expenditures associated with increased boating, hiking, birdwatching, or beach visitation that may result from the project implementation.
- Our study uses IMPLAN to examine the regional economic benefits associated with short-term construction/installation phases of restoration projects.

- **Direct effects** are production changes or expenditures that result from an activity or policy. In this analysis, direct effects are equal to the costs of the MA DER project, which we assign to appropriate economics sectors.

- **Indirect effects** are the "ripple" impact of local industries buying goods and services from other local industries as a result of the project (e.g., restoration project requires purchasing plant seeds or cement) within Massachusetts. Additional impacts that occur outside of Massachusetts are not included in these effects.

- **Induced effects** are changes in household consumption arising from changes in employment and associated income (which in turn results from direct and indirect effects) in Massachusetts. For example, these may include additional spending by construction workers with their wages, as well as additional spending by seed growers or cement companies with income received from sales for use in the restoration project.

Limitations

Final

- 2009 data, model is static in nature.
- Economic activity that does not occur in Massachusetts does not appear in our cost estimates ("leakage").
- We only look at short-term effects. While long-term effects may be substantial, they are harder to measure and require more data.
- Model is linear.

Description of projects

- Broad Meadows Restoration, Quincy, MA
  Excavation of 60 acres of dredge spoils; re-creation of tidal creek system and salt marsh.

- Eel River Headwaters Restoration, Plymouth, MA
  Six dams removed, two culverts replaced, 40 acres of wetland restored in former cranberry bog.

- Stony Brook Restoration, Brewster, MA

- North Hoosic River Restoration, Clarksburg, MA
  Dam removal provided upstream flood mitigation benefit and multiple fish and wildlife benefits.

IMPLAN inputs - Broad Meadows

Final

COST CATEGORY	MA EXPENDITURES	CLASSIFICATION
Study / Environmental Assessment	$360,000	ENG
Plans and Specifications	$556,000	ENG
Construction Contract	$3,870,500	CONSTR
Construction Contingency	$200,000	CONSTR
Engineering During Construction	$87,000	ENG
Engineering / Construction Oversight	$321,000	ENG
Monitoring and O&M Manual	$25,000	GOV
TOTAL	**$5,419,500**	

IMPLAN inputs - Eel River

Final

CATEGORY	TOTAL COST	MA PORTION	MA COSTS	CLASSIFICATION
Engineering / Design	$327,566	none	$0	ENG
Implementation	$1,121,610	all	$1,121,610	CONSTR
Engineering Oversight	$159,723	80% (estimated)	$127,778	ENG
Police Detail	$8,961	all	$8,961	GOV
Construction materials	$480,690	95% (estimated)	$456,656	CEMENT / CONCRETE PIPE
Planting / landscaping material	$165,618	95% (estimated)	$157,337	GREENHOUSE / LANDSCAPING
DER Project management / permitting	$30,000	all	$30,000	GOV
Misc. construction costs	$27,395	all	$27,395	CONSTR
Town of Plymouth management	$117,880	all	$117,880	GOV
TOTAL	**$2,439,443**		**$2,047,617**	

IMPLAN inputs- Stony Brook

Final

CATEGORY	TOTAL COST	MA PORTION	MA COSTS	CLASSIFICATION
Engineering / Design	$204,942	all	$204,942	ENG
Cultural Resources	$50,501	none (all RI)	$0	ENG
Environmental Permitting	$59,678	all	$59,678	GOV
Implementation	$650,073	all	$650,073	CONSTR
Utilities Reconfiguration	$120,586	all	$120,586	CONSTR
Bid Prep, Engineering Oversight	$50,000	all	$50,000	ENG
Culvert casting, delivery	$90,985	none (all NH)	$0	CONCRETE PIPE
DER Project management / permitting	$20,618	all	$20,618	GOV
Ecolo_ical monitorin_ 2 years	$60,842	all	$60,842	GOV
Project audit, 2 years	$11,500	all	$11,500	GOV
Partner in-kind	$40,000	all	$40,000	NGO
TOTAL	**$1,359,725**		**$1,218,239**	

IMPLAN inputs – North Hoosic River (Briggsville)

Final

CATEGORY	TOTAL COST	MA PORTION	MA COSTS	CLASSIFICATION
Engineering / Design	$171,057	75% (estimated)	$128,292	ENG
Implementation	$246,750	95% (estimated)	$234,412	CONSTR
Sediment disposal	$110,000	all	$110,000	CONSTR
Engineering Oversight	$45,530	none (all CT or VT)	$0	ENG
Planting / landscaping	$19,500	all	$19,500	CONSTR
Construction materials	$105,750	95% (estimated)	$100,462	CONCRETE PIPE / CONCRETE
Planting / landscaping material	$13,000	all	$13,000	GREENHOUSE / NURSERY
DER Project management / permitting	$22,100	All	$22,100	GOV
Partner in-kind	$5,000	all	$5,000	NGO
TOTAL	**$ 738,687**		**$627,767**	

Definitions: Impact Metrics

Final

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action. In the input-output model employed in this analysis (IMPLAN), outputs are annual production estimates for the year of the dataset (2009 in this case) and are in producer prices.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.* In other words, it is the dollar value of the net additional economic activity related to a project. This measure is analogous to the measurement of gross state product (GSP) at the State level. Included in this measure are payroll taxes, state and local sales and excise taxes, and property taxes, among other tax types.
- **Labor Income** is a measure of the employment income received in Massachusetts as part of the employment demand, and includes wages, benefits, and proprietor income.
- **Employment Demand:** Employment Demand, in this context, measures the number of additional employees necessary for the Construction/Installation and Operations Phases of projects, and is measured in "worker-years." Some employment demand reflects new permanent jobs (e.g., if a new facility requires employees for operations), but much of the demand is for additional short-term construction labor or other services. Employment is defined by the Bureau of Labor Statistics as "the total number of persons on establishment payrolls employed full or part time who received pay for any part of the pay period that includes the 12th day of the month." Temporary and intermittent employees are included. Bureau of Labor Statistics, Current Employment Statistics. Accessed at http://www.bls.gov/ces/cescope.htm#3).

*The input-output model employed in this analysis (IMPLAN) defines value added as the sum of: employee compensation, taxes on import and production and imports less subsidies (includes sales and excise taxes, customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments), and gross operating surplus (a profits-like measure that includes proprietors' income, corporate profits, net interest, and business transfer payments). IMPLAN glossary, February 2011. Accessed at http://implan.com.

IMPLAN Results – Broad Meadows ($5.4 million)

Final

IMPACT TYPE	EMPLOYMENT	LABOR INCOME	TOTAL VALUE ADDED	OUTPUT
Direct Effect	39.3	$2,990,000	$3,230,000	$5,430,000
Indirect Effect	11.1	$693,000	$1,040,000	$1,660,000
Induced Effect	19.6	$1,010,000	$1,780,000	$2,834,000
Total Effect	**70.0**	**$4,690,000**	**$6,050,000**	**$9,920,000**

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.
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- **Direct effects** are production changes or expenditures that result from an activity or policy.
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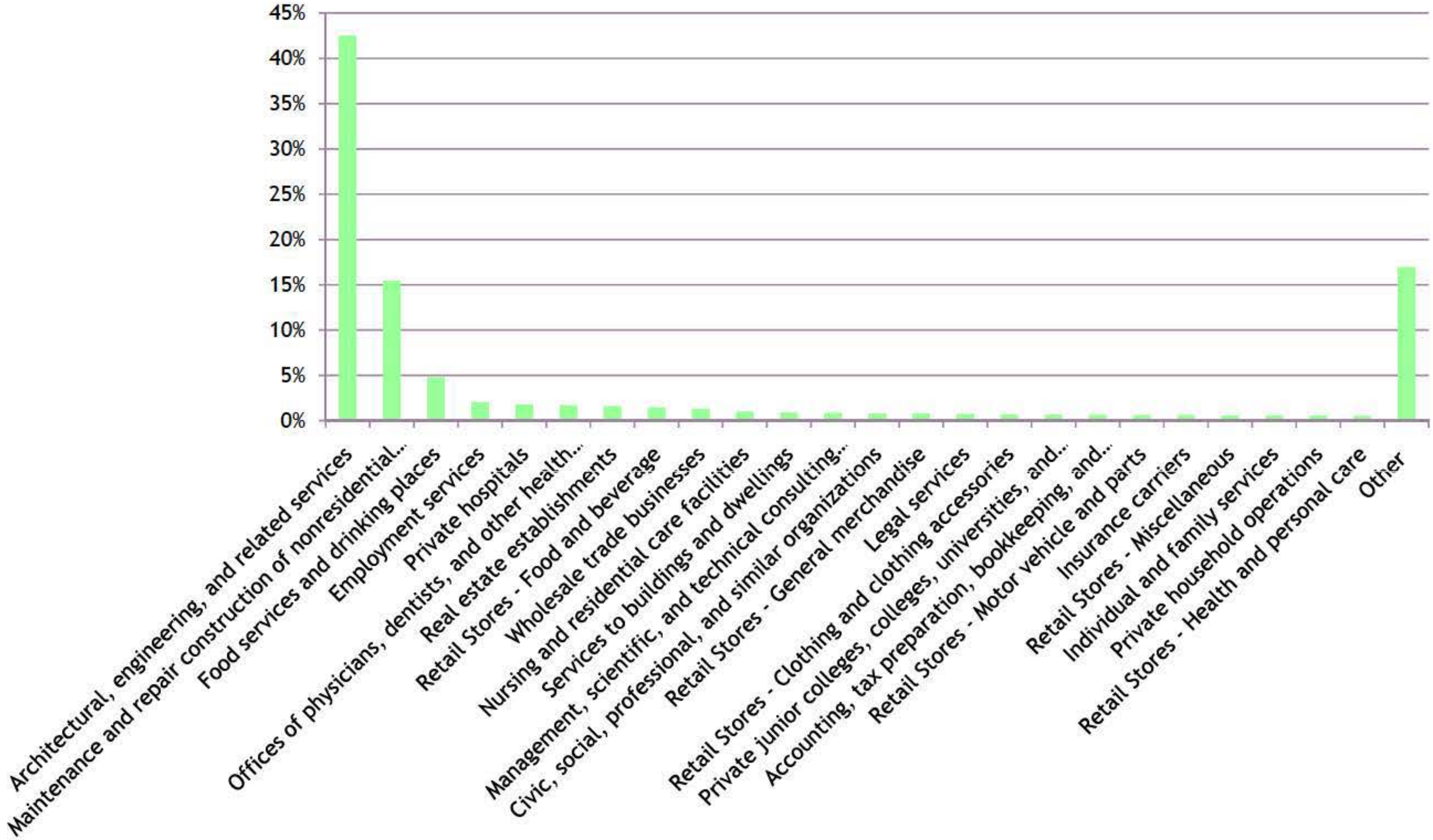
IMPLAN Results: Broad Meadows Employment Impacts Detail



IMPLAN Results – Eel River ($2.4 million)

Final

IMPACT TYPE	EMPLOYMENT DEMAND	LABOR INCOME	TOTAL VALUE ADDED	OUTPUT
Direct Effect	15.2	$884,000	$1,100,000	$1,950,000
Indirect Effect	3.1	$197,000	$303,000	$507,000
Induced Effect	5.8	$297,000	$522,000	$833,000
Total Effect	**24.1**	**$1,380,000**	**$1,920,000**	**$3,280,000**

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.
- **Labor Income** is a measure of the em, lo, ment income received in Massachusetts as , art of the em, lo, ment demand, and includes wa, es, benefits, and proprietor income.
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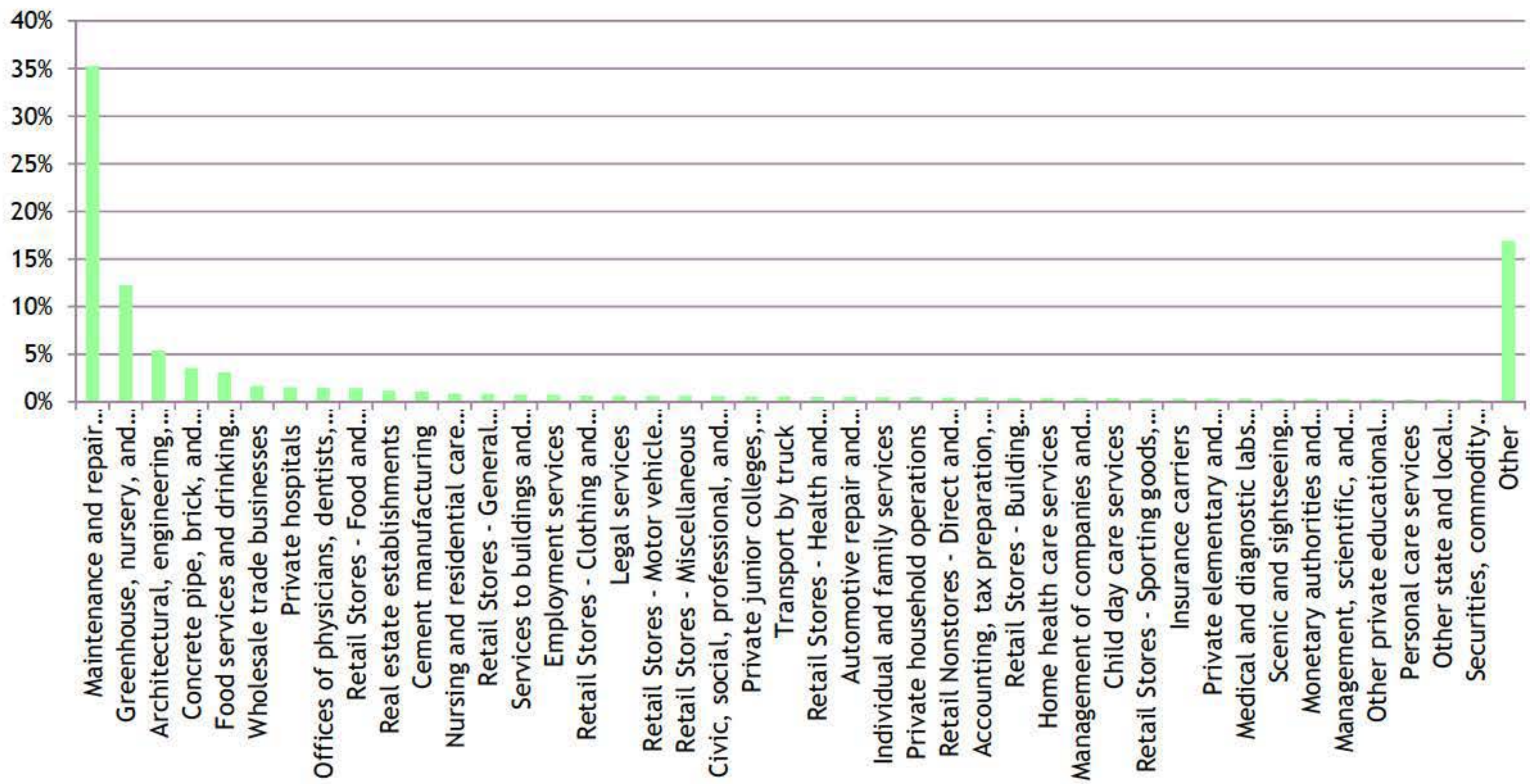
- **Induced effects** are changes in household consumption arising from changes in employment and associated income (which in turn results from direct and indirect effects) in Massachusetts.

IMPLAN Results: Eel River Employment Impacts Detail

Final



IMPLAN Results – Stony Brook ($1.4 million)

Final

IMPACT TYPE	EMPLOYMENT DEMAND	LABOR INCOME	TOTAL VALUE ADDED	OUTPUT
Direct Effect	[illegible]	$542,000	$618,000	$1,090,000
Indirect Effect	1.9	$122,000	$184,000	$299,000
Induced Effect	3.5	$182,000	$320,000	$512,000
Total Effect	**14.1**	**$846,000**	**$1,120,000**	**$1,900,000**

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.
- **Labor Income** is a measure of the employment income received in Massachusetts as part of the employment demand, and includes wages, benefits, and proprietor income.
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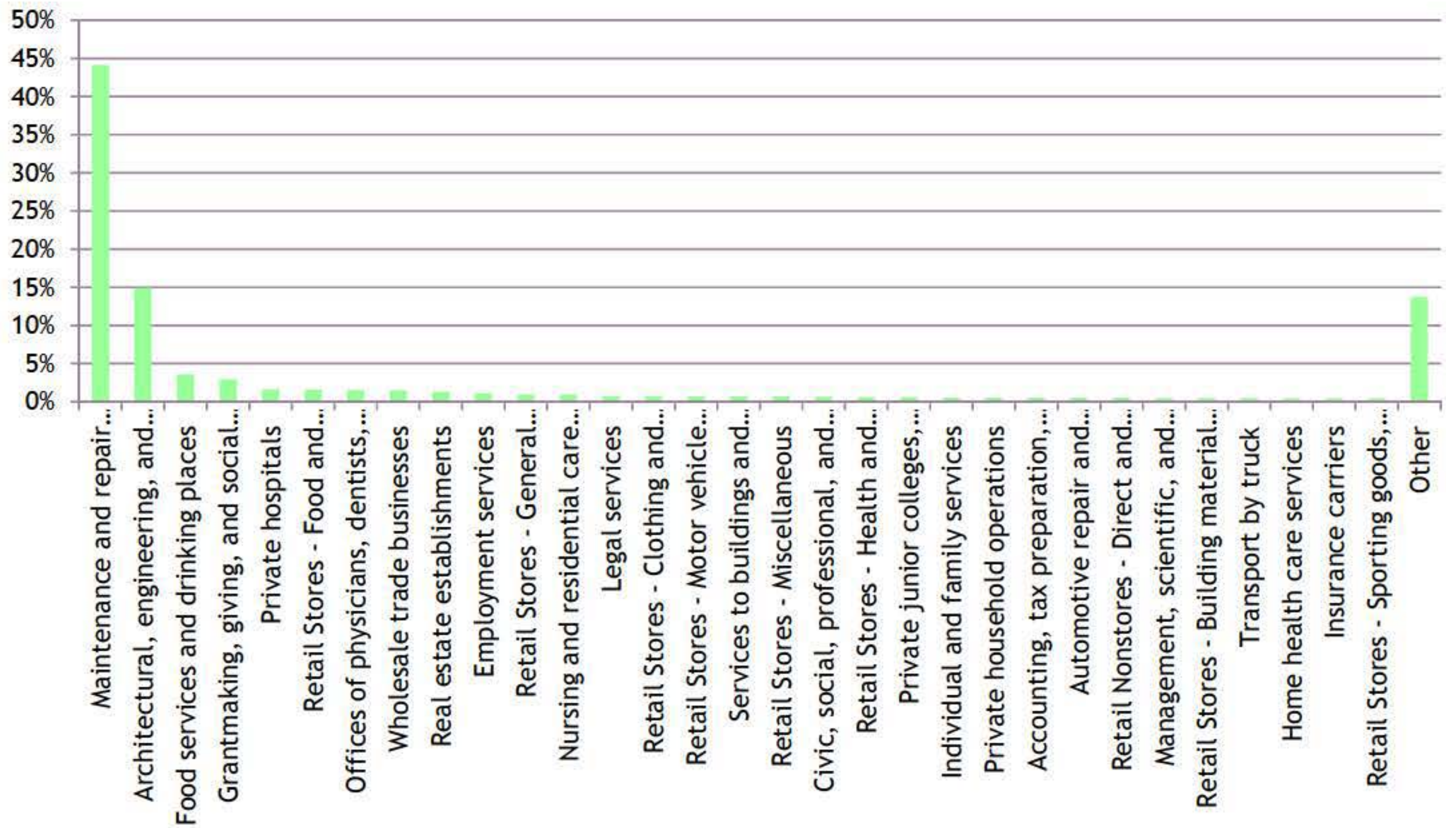
- **Indirect effects** are the "ripple" impact of local industries buying goods and services from other local industries as a result of the project (e.g., restoration project requires purchasing plant seeds or cement) within Massachusetts.
- **Induced effects** are changes in household consumption arising from changes in employment and associated income (which in turn results from direct and indirect effects) in Massachusetts.

IMPLAN Results: Stony Brook Employment Impacts Detail

Final



IMPLAN Results – North Hoosic River ($0.7 million)

Final

IMPACT TYPE	EMPLOYMENT DEMAND	LABOR INCOME	TOTAL VALUE ADDED	OUTPUT
Direct Effect	4.6	293,000	354,000	633,000
Indirect Effect	1.1	$69,900	$107,000	$176,000
Induced Effect	1.9	$99,600	$175,000	$279,000
Total Effect	**7.6**	**$462,000**	**$635,000**	**$1,090,000**

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.
- **Labor Income** is a measure of the employment income received in Massachusetts as part of the employment demand, and includes wages, benefits, and proprietor income.
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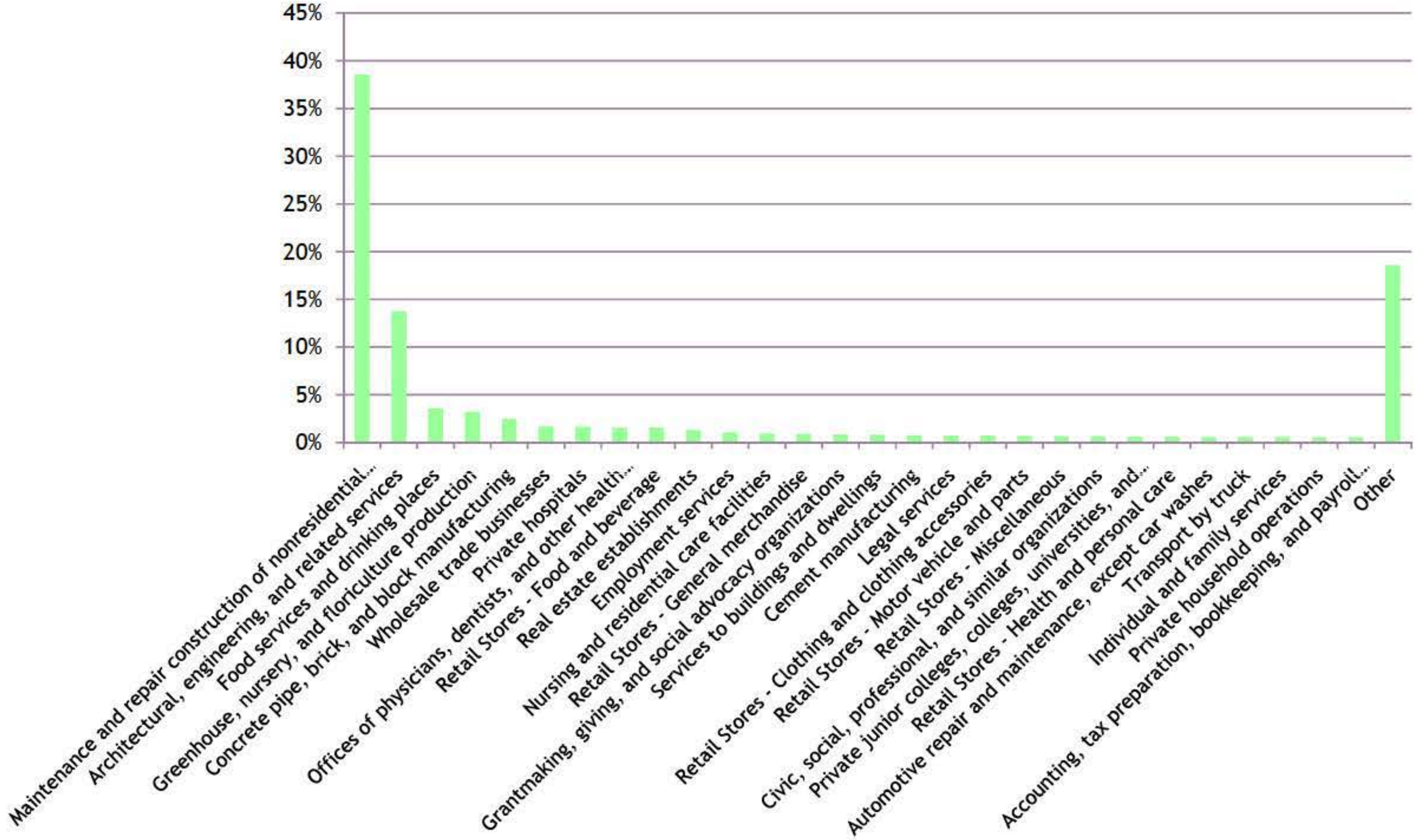
IMPLAN Results: North Hoosic River Employment Impacts Detail

Final



Sensitivity of Results: Results if all costs are assumed to be incurred in MA

Final

IMPACT TYPE	EMPLOYMENT DEMAND	CHANGE	LABOR INCOME	CHANGE	TOTAL VALUE ADDED	CHANGE	OUTPUT	CHANGE
Broad Meadows*	70.0	0%	$4,690,000	0%	$6,050,000	0%	$9,920,000	0%
Eel River	32.2	+34%	$1,904,000	+38%	$2,620,000	+36%	$4,440,000	+35%
Stony Brook	16.1	+14%	$969,000	+15%	$1,290,000	+15%	$2,220,000	+17%
North Hoosic River	9.0	+17	$540,000	+17%	$740,000	+17%	$1,270,000	+17%

*All Broad Meadows impacts already assumed to be in MA in primary scenario.

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
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- **Induced effects** are changes in household consumption arising from changes in employment and associated income (which in turn results from direct and indirect effects) in Massachusetts.

Summary of Impacts: per $1M Investment*

Final

IMPACT TYPE	EMPLOYMENT DEMAND	LABOR INCOME	TOTAL VALUE ADDED	OUTPUT
Broad Meadows	12.9	$865,000	$1,120,000	$1,830,000
Eel River	9.9	$565,000	$789,000	$1,350,000
Stony Brook	10.4	$622,000	$826,000	$1,400,000
North Hoosic River	10.4	$626,000	$860,000	$1,470,000

*Assumes some direct expenditures not spent in MA.

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.
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- **Induced effects** are changes in household consumption arising from changes in employment and associated income (which in turn results from direct and indirect effects) in Massachusetts.

Summary of Impacts: per $1M Investment, all MA scenario*

Final

IMPACT TYPE	EMPLOYMENT DEMAND	LABOR INCOME	TOTAL VALUE ADDED	OUTPUT
Broad Meadows	12.9	$865,000	$1,120,000	$1,830,000
Eel River	13.2	$781,000	$1,070,000	$1,820,000
Stony Brook	11.8	$713,000	$949,000	$1,630,000
North Hoosic River	12.2	$731,000	$1,000,000	$1,720,000

*Assumes ALL direct expenditures are spent in MA.

- **Output:** Output is defined as the total economic activity or value of production in the state that is generated by an action.
- **Value Added:** Value added is defined in economic modeling as the difference between an industry's or establishment's total output and the costs of its intermediate inputs.
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Literature review

Final

- Purpose is to compare our results to those presented in similar studies.
- Four studies included in our review:
  - Ecotrust, *Preliminary Economic Assessment of Dam Removal: The Klamath River*, January 31, 2006
  - Montana Departments of Natural Resources and Conservation and Labor and Industry, *An Estimation of Montana's Restoration Economy*, September 2009
  - University of Oregon, Institute for a Sustainable Environment, *Economic and Employment Impacts of Forest and Watershed Restoration in Oregon*, Spring 2010
  - University of Massachusetts, Political Economy Research Institute, *How Infrastructure Investments Support the U.S. Economy: Employment, Productivity and* Growth, January 2009

Literature review – Klamath River dam removal

Final

- Prospective analysis of the benefits of removing four dams from the Lower Klamath (and restoring upstream access for salmon).
- Applies Regional Input-Output Modeling System (RIMS) II multipliers for California.
- "Jobs created" per $1M in construction expenditures: **21.5**
- Indirect and induced jobs per job created: **2.1**
- Dollar change in total output per expenditure dollar: **2.4**

In addition:

- Jobs created per 1,000 commercially caught salmon: **1.5**
- Jobs created per 1,000 recreationally caught salmon: **4**

Literature review – OR forest/watershed restoration

Final

- Application of IMPLAN 3.0 to estimate impact of public investments (random sample of 99 Oregon Watershed Enhancement Board restoration grants).

- Modeled four types of *contracted* restoration work:
  - Equipment-intensive watershed work (e.g., stream habitat construction)
  - Equipment-intensive forestry work (e.g., forest thinning)
  - Labor-intensive work (e.g., site prep, tree planting)
  - Technical planning and design work (e.g., field surveys, planning document development)

- Separately modeled projects by combining *contracting model* with a *project management* model.

Literature review – OR forest/watershed restoration

Final

For each $1M invested in <u>contracted</u> work:

- Total employment effect (direct, indirect, induced): **15.7 - 23.8 jobs**
- Total economic output: **$2.1M - $2.4M**

For each $1M invested in a restoration project
(assuming 55% project management, 45% contracted costs):

- Total employment effect (direct, indirect, induced): **14.7 - 23.1 jobs**
- Total economic output: **$2.2M - $2.5M**

Authors' observations and conclusions:

- Use of economic models built on characterization of "traditional" activities can limit the accuracy of estimated impact of investment in a new/emerging sector.
- In general, labor-intensive contracting creates less economic activity than equipment-intensive contracting, but more jobs
- IMPLAN reflects an urban bias; modifications necessary when work is largely rural.

Literature review – Montana restoration economy

Final

- Application of IMPLAN to mining-related restoration activities
- Total employment effect (direct, indirect, induced) per $1M in restoration funding: **31.53** jobs
- Total economic output per $1M in restoration spending: **$2.59M**
- Authors note the impermanence of jobs and economic output and the possibility that calculated multipliers in this mining-related restoration context may not be readily transferable.

Literature review – UMass infrastructure investment

Final

- Application of IMPLAN to estimate the impact of infrastructure investment in key sectors.
- Supplemental results by industry include the "reforestation, land and watershed restoration, and sustainable forest management" sector.
- Total employment effect (direct, indirect, induced) per $1M invested in this sector: **39.7** jobs

Concluding observations

Final

- Our work is generally in line with other findings from similar efforts.
- Impacts across the four projects were not significantly different in terms of short-term impacts per $1M investment.
- Broad Meadows had somewhat higher impacts per $1M effort—this is likely the difference from assuming all activity occurs in MA.

A Research Paper by

HEADWATERS ECONOMICS

Dam Removal:

Case Studies on the Fiscal, Economic, Social, and Environmental Benefits of Dam Removal

October 2016

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PUBLISHED ONLINE:
http://headwaterseconomics.org/economic-development/local-studies/dam-removal-case-studies

ABOUT HEADWATERS ECONOMICS

Headwaters Economics is an independent, nonprofit research group whose mission is to improve community development and land management decisions in the West.

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[redacted]

[redacted] Whittenton Pond Dam, Mill River, Massachusetts. American Rivers.

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INTRODUCTION

Since the 18th century, dams have been built across the United States to power mills, provide downstream flood control, facilitate transportation, provide irrigation water, and generate hydroelectricity. Presently there are more than two million dams across the country (William 1993), and a federal inventory has identified more than 87,000 dams across the United States that are more than six feet tall (CorpsMaps National Inventory of Dams 2013).

Over time these dams have aged. By 2020, 70 percent of dams in the United States will be more than 50 years old (2013 report card…2013). The Association of State Dam Safety Officials—a national non-profit serving state dam safety programs—estimates it could cost $51.5 billion to rehabilitate the nation's non-federally owned dams (Association of State Dam Safety Officials 2009).

At the same time, economies and energy needs have shifted, and ecological research has advanced. Regulations like the Clean Water Act (CWA) and Endangered Species Act (ESA), state water and fisheries regulations, and tribal rights claims have elevated water quality, fish, and tribal claims where dams are concerned.

While some dams continue to serve useful purposes, others have outlived their original function. For these obsolete dams, the benefits to the public of removing them outweighs the costs. In light of aging infrastructure, it is appropriate to evaluate individual dams to determine whether their ongoing costs and effects on rivers and people justifies the services they provide.

Agencies like the U.S. Army Corps of Engineers (USACE) and the Federal Energy Regulatory Commission (FERC) have established processes to evaluate benefits and costs as a part of various agency programs.

Licensing decisions at FERC, for example, consider multiple management scenarios when evaluating whether to issue new or renew existing dam licenses. The management scenarios may require dam owners to allow greater water flow through the dam, install infrastructure to allow migratory fish to pass upstream, or make safety upgrades. Often the options include a dam removal scenario. These evaluations also include impact assessments that evaluate the benefits and costs to the many parties affected by each management alternative.

The USACE undertakes similar analyses when it evaluates its dams and other river restoration programs. Some dam owners have found that removing a dam is more appropriate than leaving it in place after comparing benefits and costs of addressing the needs of concerned parties and meeting state and federal regulatory requirements.

Since 1912, more than 1,300 dams have been removed across the U.S., and 62 dams were removed in 2015 alone (American Rivers 2016).

This report describes the methods used to measure the benefits of dam removal when comparing costs to benefits, including five case studies and a summary of small dams. The case studies illustrate the range of benefits and costs that can be considered, multiple methodological approaches, and a range of locations.

The case studies range from small former mill sites to large western hydropower dams, including:

- Whittenton Pond Dam on the Mill River in Massachusetts;
- Elwha and Glines Canyon Dams on the Elwha River in Washington;
- Edwards Dam on the Kennebec River in Maine;
- Condit Dam on the White Salmon River in Washington;

- Great Works and Veazie Dams on the Penobscot River in Maine; and
- Three small dam removals including Hyde Pond Dam on Whitford Brook in Connecticut, Bartlett Pond Dam on Wekepeke Brook in Massachusetts, and White Rock Dam on Pawcatuck River in Connecticut and Rhode Island.

MEASURING THE BENEFITS OF DAM REMOVAL

The circumstances for individual dam removal projects are wide-ranging and depend on unique combinations of environmental, historic, and economic factors. The following sections describe the most common reasons for removing dams and how those factors have been quantified. Examples of some benefit-cost comparisons are described in detail in the Case Studies.

In addition, at the end of this section and the Conclusion, Table 1 summarizes benefits by each case study, including the estimated costs of dam removal, the types of benefits, and the alternatives to dam removal that were considered.

Throughout this report, all dollar values have been converted to 2016 dollars.

Cost-Effectiveness of Maintenance Versus Removal

Dams require ongoing maintenance to remove accumulating sediment, make small repairs, and upgrade safety systems. Particularly when older dams are no longer used for their original purpose, dam owners may defer maintenance to the point where the dams pose a threat to public safety (see Whittenton Pond Mill Dam case study). In these cases, it is appropriate for dam owners to work with state and federal experts to figure out how to protect communities. In some cases, it is less expensive to remove the dam than to make the necessary repairs (see Small Dams case study).

Many dam removal decisions have been made after the costs of maintenance or upgrades have been compared with costs of removal.

Vulnerable Species and Other Ecological Benefits

Dams interfere with the life cycle of migratory fish by blocking the migration of adults to upstream spawning grounds, as well as limiting the passage of sediment and large woody debris necessary to maintain suitable spawning areas downstream (Brenkman et al. 2012). Fish passage devices at dams allow some fish to move upstream, but the success rate varies depending on the dam height and the species (Brown et al. 2013).

Dams can be significant impediments to the recovery of vulnerable fish species, including those listed as threatened or endangered under the Endangered Species Act. Removing one dam can open hundreds of miles of upstream spawning habitat in a river's main stem and tributaries, such as the Great Works and Veazie Dams in Maine.

In several cases, the Endangered Species Act has been the catalyst for dam removal due to mandated changes to river management to increase populations of endangered species. In cases such as the Glines Canyon Dam on the Elwha River, which was too high for fish ladders, fish passage facilities are insufficient to restore fish populations. In cases such as the Condit Dam on the White Salmon River, retrofitting the dam to allow fish passage would have been more expensive than removing the dam.

Follow-up population studies after dam removal have found that species quickly return to upstream spawning habitat, even when the river has been blocked for 100 years (Penobscot River Restoration Trust et al., NPS 2014).

Researchers have measured a cascade of ecological improvements associated with dam removal, including: more robust plant and animal health in upper watersheds due to ocean-derived nutrients transported upstream by migrating fish (Tonra et al. 2015); improved health of plants and animals in estuaries and river mouths due to more abundant sediment (Baurick 2015); and improved water quality (Bednarek 2001).

Cultural Values

In addition to subsistence and commercial fish harvests, many Native American tribes have deep cultural, spiritual, and historical connections to specific free flowing rivers, features along those rivers, and the animal and plant species they support. Dams often severely harmed those resources, and were installed with little or no consideration of nearby tribes and their rights (Guarino 2013).

Tribes continue to play significant roles in demonstrating the importance of removing dams. The Edwards Dam in Maine and Elwha and Glines Canyon Dams in Washington are examples of dam removal efforts where a local tribe provided much of the initial impetus for removing dams, and were among the greatest beneficiaries of their removal.

Recreational and Commercial Fisheries

Removing dams also can increase the abundance of commercially and recreationally targeted fish species.

Benefits to commercial fisheries are measured in terms of increased revenue from improved catch rates (Meyer et al. 1995). Benefits to recreational anglers are measured in terms of improved experiences due to increased catch rates and species diversity, discussed in the Non-Market Values section. Benefits from improved recreational fishing also are measured in terms of additional jobs and income supported by more visiting anglers (Meyer et al. 1995).

River Recreation and Other Tourism

Removing dams and returning rivers to a free-flowing state can provide new boating opportunities, particularly for whitewater rafting, canoeing, and kayaking. This provides increased enjoyment for the paddlers, which can be measured by the increased number of boaters and the quality of their experience (Loomis 1999).

Neighboring communities benefit from increased whitewater recreation and other river-related tourism when visitors spend money with local guides, outfitters, restaurants, and other businesses, bringing new money to oftentimes remote communities (Meyer et al.1995).

Non-Market Values

People value seemingly unquantifiable outdoor amenities like free-flowing rivers, endangered species, and recreational opportunities. Researchers are able to apply statistical methods to measure how much people value selected environmental qualities and then translate that value into dollars. These "non-market values" can then be incorporated into cost-benefit analyses.

Non-market values often are used to weigh pros and cons when a federal project will result in large environmental impacts. Since the 1970s the Federal Energy Regulatory Commission (FERC) has considered non-market values in relicensing decisions, due in large part to the passage of the Endangered Species Act and methodological refinements for measuring non-market values (Duffield 2011).

Researchers have found that people place substantial value on the following environmental changes associated with removing dams:

- The existence of a free-flowing river that individuals can see now or in the future, or will be available for their children to visit (Loomis 1996, Loomis 2002, Sanders 1990);
- Knowledge that endangered species are present in a river and their population is recovering (Mansfield et al. 2012, Bell et al. 2003, Berrens et al. 2000, Ekstrand and Loomis 1998);
- Improved catch rates for recreational anglers (Kotchen et al. 2006, Layton et al. 1999, Boyle et al. 1991, Olsen et al 1991, Bishop et al. 1987); and
- Improved experiences for whitewater boaters (Loomis 1999, Gloss et al. 2005).

The Elwha and Glines Canyon Dams case study, for example, describes research that found the American public would be willing to pay approximately $5.3 billion per year to remove the dams and restore the river (Loomis 1996).

Non-market benefits are distinct from the additional spending that anglers and tourists bring to an area. Because the benefits are experienced by people close to the dam as well as those who live far away, total non-market benefits can be quite large and therefore influential in FERC relicensing decisions.

Cost-Effectiveness of Energy Production

Many older hydroelectric dams were built to support nearby mills, factories, and communities, and have relatively small generating capacity. As the U.S. power grid has shifted to more regional rather than local production, power produced by smaller dams can be more expensive than power from regional sources (see Edwards Dam case study) or may no longer be needed if the nearby industrial user has closed (see Elwha Dams case study).

In these cases, the end users are able to secure sufficient electricity generating capacity from less expensive sources, eliminating the original need for the dam.

Economic Impact of Removal Projects

Dam removal and associated river restoration can be substantial, multi-year projects, employing local residents, providing personal income, and contributing to the local economy. Jobs associated with these removal projects often are relatively short-term, but nonetheless valuable particularly in smaller communities.

A 2012 study found that every $1 million spent on Massachusetts Division of Ecological Restoration projects resulted in 10 to 13 jobs created or maintained (Industrial Economics Inc. 2012). A 2010 study in Oregon finds that every $1 million spent on forest and watershed restoration results in 15-23 new jobs and $2.1-2.3 million in economic activity (Nielsen-Pincus and Moseley 2010).

Property Values

Researchers have found that some dams, particularly small dams with small upstream impoundments, can create an unpleasant feature that drives down property values due to lower water quality or flooding risk.

On the Kennebec River in Maine, researchers found that before the Edwards Dam was removed, homes closer to the river had significantly lower property values than similar homes farther from the river. After the dam was removed, there was no longer a price penalty to living closer to the river (Lewis et al. 2008).

A study on numerous small dams in Wisconsin found a similar pattern (Provencher et al. 2008).

CONCLUSION

Dam removal decisions are complex, requiring owners and regulators to weigh a dam's current value in accomplishing its original purpose—such as flood control, agriculture, recreation, and power generation—against the dam's ongoing effects on public safety, water quality, fish and other species, recreation, and cultural values. These considerations also must be evaluated in the context of long-term maintenance costs and costs of removal.

As the thousands of dams in the United States have aged, the upkeep expenses and the need for significant repairs have risen for many dams. At the same time, scientific research has improved our understanding of river systems and the effects dams have on a region's environmental health. Advances in economic methods also have improved our understanding of the economic benefits to nearby communities, river users, and the broader public from free-flowing rivers.

Together, the higher ongoing costs of operating dams and an improved awareness of the economic and social benefits of removing them has shifted the balance sheet for some dams. For these dams, removal often provides greater rewards to taxpayers, local economies, and the surrounding environment. Additionally, funding for removal projects often can be gathered from several sources as different agencies, organizations, and communities better understand how they can benefit from dam removal.

The case studies that follow, summarized in Table 1 below, highlight the many factors that contribute to dam removal decisions, how these factors have been weighed, and the process that led to a dam's removal. This review demonstrates that in many cases the economic, environmental, and social benefits of dam removal outweigh the costs of keeping a dam in place.

Table 1: Case Studies, Benefits of Dam Removal, and Alternatives Considered

Location	Estimated cost of removal (2016$)	Estimated benefits of removal (2016$)	Alternatives to dam removal
Whittenton Pond Dam, Mill River, Massachusetts	$447,000: 99 percent paid by state and federal partners, non-profits	• $1.5 million for avoided emergency response • Increased numbers of two vulnerable species: American eel and river herring • Property values projected to increase due to lower flooding risk	Rebuilding was necessary due to disrepair and safety hazard, cost estimated at $1.9 million
Elwha and Glines Canyon Dams, Elwha River, Washington	$324.7 million	• $5.3 million annually from increased commercial fishing • Cultural and public safety benefits to the Lower Elwha Klallam Tribe, downstream from the dams • $33 million in personal income and 760 new jobs associated with dam removal • $43.8 million and 446 new jobs from 500,000 more visitor days annually • $5.3 billion worth of improved well-being for the American public	Not available
Edwards Dam, Kennebec River, Maine	$10.9 million	• $2.5-$38.2 million for improved recreational fishing quality • $397,000-$2.7 million for improved river recreation quality • Property values closest to the former dam site increased • Electricity produced by Edwards Dam cost 4-5 times the market rate • Water quality prior to dam removal did not meet minimum standards; afterward it could support all native fish • Alewife population increased 60-fold, and they now are used commercially for bait • Quality of life in Augusta has improved due to new connection to the river	$14.9 million to install fish passages and conduct environmental mediation

Location	Estimated cost of removal (2016$)	Estimated benefits of removal (2016$)	Alternatives to dam removal
Condit Dam, White Salmon River, Washington	$24.8 million	• Cultural benefits for the Yakama Nation from returned salmon and lamprey, including sustenance fishing • Expanded spawning grounds for recreationally and commercially important fish: 12 miles for salmon and 33 miles for steelhead • Increased populations of five fish species listed under the Endangered Species Act • 30,000 additional whitewater boaters annually	$52.4 million for fish passages, plus $3.9 million annually in higher electricity costs
Great Works and Veazie Dams, Penobscot River, Maine	$65 million	• 76 jobs and $3.6 million in economic impact from dam removal • Access re-opened for 1,000 miles of habitat for 11 depleted historic fisheries • Cultural and sustenance fishing benefits for the Penobscot Indian Nation • New area spending by whitewater boaters, including several events.	Fish passage facilities were insufficient to restore fisheries
Small Dams: Hyde Pond Dam, Whitford Brook, Connecticut	$1.1 million	• Avoided public safety hazards from catastrophic failure and upstream flooding • Four miles of stream habitat opened to fish species including American eel, a vulnerable species	Dam would have to be rebuilt to meet safety standards. Dam owner would have been responsible for full cost of rebuilding dam
Small Dams: Bartlett Pond Dam, Wekepeke Brook, Massachusetts	$325,000	• Avoided public safety and infrastructure hazards from catastrophic failure and upstream flooding • Eighteen miles of stream habitat opened for brook trout and other species	$671,000 for repairs
White Rock Dam, Pawcatuck River, Connecticut and Rhode Island	$800,000	• Avoided public safety and infrastructure hazards from catastrophic failure and upstream flooding • Twenty-five miles of river habitat opened to fish species	Dam would have to be rebuilt to meet safety standards. Dam owner would have been responsible for full cost of rebuilding dam

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WHITTENTON POND DAM, MILL RIVER, MASSACHUSETTS

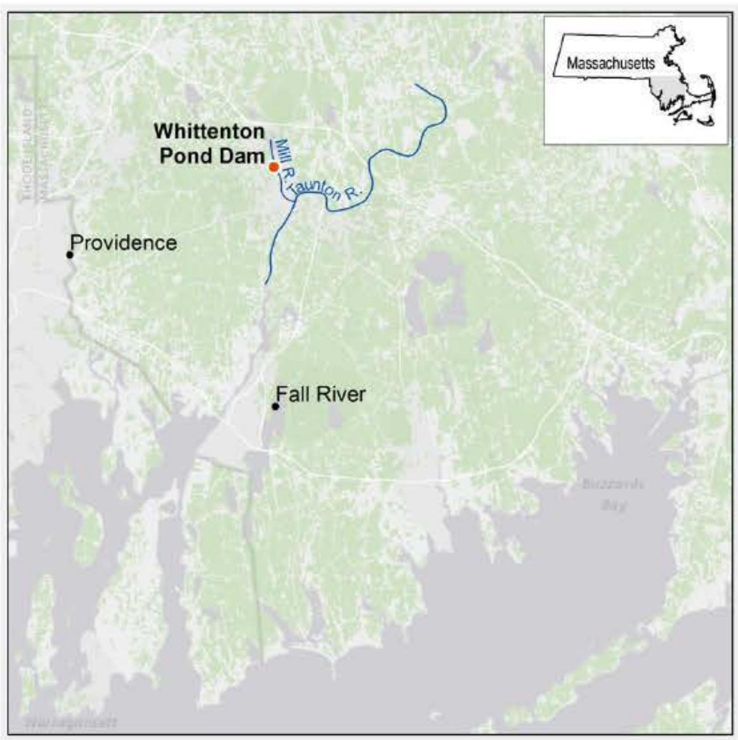
Overview

The Whittenton Pond Dam in Taunton, Massachusetts was in disrepair and the potential for a catastrophic breach was a significant risk to downstream communities. Removing the dam was less expensive than repairing it, and its removal in 2013 opened 30 miles of river habitat to vulnerable fish species.

Dam Removal Process

The Whittenton Pond Dam was a privately-owned dam located in Taunton, Massachusetts on the Mill River. The 10-foot- high and 120-foot-wide wood and concrete structure originally was built in 1832 to power a textile mill. When the mill closed, the dam was no longer maintained.

Heavy rains in 2005 brought the threat of a catstrophic breach and flooding of downtown Tauton, which was evacuated for a week as the dam appeared on the verge of failure (MDFG 2015). Around this time, the dam owner also decided it would be prudent "to remove the dam in order to reduce liability and avoid the cost of rebuilding the dam" (MDFG 2015).



Primary Benefits

Cost Effectiveness: Removing the dam cost less than one-quarter of the cost of necessary repairs.

Avoided Emergency Response Cost: Without the threat of a catastrophic dam breach, taxpayers avoid emergency response costs of more than $1.5 million.

Vulnerable Species: Dam removal opened access to historical habitat for a number of species, including vulnerable American eel and river herring.

Property Values: Due to reduced flooding risk, dam removal is expected to increase values for properties upstream and downstream of the dam site.

Benefits of Dam Removal

Removing the Whittenton Pond Dam is associated with four main types of benefits: cost effectiveness compared to other management alternatives, avoided emergency response cost, protection of vulnerable species, and increased property values.

Cost Effectiveness

In 2008, Massachusetts Division of Ecological Restoration (DER) and the Southeastern Regional Planning and Economic Development District commissioned a feasability assessment of removing the dam, including no-action, dam removal, and fish passage alternatives.

Improvements to the dam were necessary to protect public safety. Due to the age and disrepair of the dam, these improvements essentially required rebuilding the dam, dramatically increasing the cost of the "no-action" alternative.

Dam removal cost $447,000 compared to $1.9 million estimated to rebuild the dam (MDFG 2015). Repair options with a fish ladder or a fish bypass channel would have cost even more than rebuilding. Due to the public safety and ecological importance of this dam removal project, together the National Oceanic and Atmospheric Administration (NOAA), American Rivers, The Nature Conservancy, and Coastal America Foundation paid for 99.5 percent of the removal costs. The dam was removed in 2013 as part of a larger effort that removed two dams on the Mill River, with a third to be removed in the next year.

Avoided Emergency Response Cost

Removing the dam represented a significant avoided cost for emergency response to a catastrophic breach, that would have been borne by state and local taxpayers. The 2015 MDFG study estimated the 2005 costs of emergency reponses were in excess of $1.5 million; a catastrophic breach likely would have cost even more.

Vulnerable Species

Removing this dam and two other Mill River dams opened more than 30 river miles of additional river habitat, benefitting two vulnerable fish species: the American eel, being evaluated for listing as threatened under the Endangered Species Act, and river herring, listed as a Species of Concern by the National Marine Fisheries Service.

Although no studies of fish recovery yet have been conducted at this dam site, just downstream of the Whittenton Pond Dam, the Hopewell Mill Dam was removed in 2012. The following year, the Massachusetts Division of Marine Fisheries (DMF) found river herring above the dam for the first time in more than 200 years (Larocque 2013). Furthermore, a 2015 news article reported that American eel had returned and are again "fairly plentiful" in the Mill River (Winokoor 2015).

BEFORE

AFTER

Photo credits: American Rivers

Property Values

Research on other dam sites in Maine and Wisconsin found that removing dams, and thereby eliminating associated small impoundments and flooding risk, results in small but consistently higher property values nearby (Provencher et al. 2008, Lewis et al. 2008). The Massachusetts Department of Fish and Game (MDFG 2015) expects to see a similar boost to local property values near the Whittenton Pond Dam site.

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ELWHA AND GLINES CANYON DAMS, ELWHA RIVER, WASHINGTON

Overview

Removal of the Elwha and Glines Canyon Dams from the Elwha River in Washington in 2012 was the largest dam removal and river restoration project in the United States to date. Before these dams were built, the river supported ten runs of salmon and trout, including all five Pacific salmon species.

Removing these two dams was the only way to restore these fish runs. This project was a unique opportunity for fishery restoration because the upper section of its watershed lies entirely in Olympic National Park, increasing the chances of successful recovery.

The cost of removing two dams and restoring the river, as well as lost power generation, were outweighed by the benefits to the Lower Elwha Klallam Tribe, nearby communities, and American public.

Dam Removal Process

Completed in 1913, the Elwha Dam was located five miles upstream from where the Elwha River empties into the Strait of Juan de Fuca. It was 105 feet high and had a 14.8 MW generation capacity.

Primary Benefits

Recreational and Commercial Fisheries: Total increased catch is expected to value approximately $5.3 million per year.

Cultural Values: Dam removal restored the river, historical fishing grounds, and cultural sites important to the Lower Elwha S'Klallam Tribe.

Dam Removal Economic Impact: The dam removal and river restoration processes are expected to add 760 new jobs and $33 million in personal income.

Tourism: The newly restored river is expected to bring 500,000 additional visitor days per year, generating $43.8 million in new spending.

Non-Market Values: The American public is willing to pay approximately $5.3 billion per year to support dam removal and river restoration on the Elwha River.

Ecological Benefits: Dam removal opened access for 40 miles of historical habitat for ten runs of salmon and trout, including ESA-listed Chinook salmon and bull trout.

The Glines Canyon Dam was completed in 1927 and was 13 miles from the Strait of Juan de Fuca. It was 210 feet high and had 13.3 MW generation capacity. Both dams were used to generate hydroelectric power for nearby paper and lumber mills.

The Crown Zellerbach Corporation (now James River Corporation) submitted an application for a FERC license in 1973. A failed safety inspection in 1978, followed by modeling of flood hazard should the dam fail, highlighted potential harm to the Lower Elwha Klallam Tribe.

The licensing process was proceeding when Congress passed the Elwha River Ecosystem and Fisheries Restoration Act in 1992, which a) removed FERC's authority to license the Elwha Project; b) required federal studies to research alternatives for full restoration of the Elwha River ecosystem and migratory fisheries; and c) authorized the Secretary of Interior to purchase and acquire both the Elwha and Glines Canyon Dams for a fixed price and then implement necessary actions to meet full restoration objectives (U.S. Congress 1992).

The Department of Interior purchased the two dams from James River Corporation in 2000 for $29.5 million. Two environmental impact statements (EIS) concluded that neither leaving the dams intact nor installing fish passages would be sufficient to restore the fisheries. As a result, the Elwha and Glines Canyon Dams were removed in 2012. The total cost of purchasing and removing the dams and hydropower facilities, and conducting river restoration activities, was $324.7 million (National Park Service 2016).

Benefits of Dam Removal

Removing the dams and restoring the river and its historic fish runs have generated wide ranging benefits for local residents and visitors, including: cultural benefits for the Lower Elwha Klallam Tribe; improved catch rates for commercial and recreational anglers; additional jobs and income from dam removal and river restoration activities; additional jobs and income from new tourism; benefits to the American public from restoring a notable river; and a suite of ecological benefits from restoring the salmon runs.

Because 83 percent of the Elwha River's watershed is located within Olympic National Park, this river represented a unique restoration opportunity.

Twenty years passed between when the Elwha River Ecosystem and Fisheries Restoration Act was passed and when the dams were removed. The research describing the benefits of dam removal therefore spans decades as well.

Recreational and Commercial Fishing

Removing the Elwha and Glines Canyon Dams provided access to an additional 40 miles of mainstem river habitat as well as tributaries. A few months after dam removal, the mainstem and its tributaries were being used by wild and hatchery salmon. In the first season after the Elwha Dam was removed, more than 4,000 spawning Chinook were counted (Mapes 2016). Scientists also observed increased sockeye salmon populations, with 400 sockeye counted in 2012 after the Elwha Dam was removed. Those counts increased to 800 and then 1,100 in 2013 and 2014 (Witze 2014).

These increased fish populations are expected to bring approximately $5.3 million dollars per year from increased total catch from tribal and non-tribal commercial fishing and recreational fishing (Meyer et al. 1995). Larger catches will likely add income and employment in the local fishing sector, but these changes have not been quantified.

Cultural Benefits

The benefits of dam removal to the Lower Elwha S'Klallam Tribe, who was a key partner in the process which ultimately led to dam removal, are immeasurable. The Tribe has lived in the area since before the beginning of recorded history, and the Elwha River and its fishery had served as the basis for the culture, economy and sustenance of the tribe, all of which were severely impacted by installation of the dams.

BEFORE

Photo credit: Thomas O'Keefe

AFTER

Photo credit: Richard Probst

Dam Removal Economic Impact

The processes of dam removal and river restoration were forecasted to add at least 760 new jobs and $33 million in new personal income to the area (Meyer et al. 1995). Data on the actual change in local jobs and income is not yet available.

Tourism

Loomis (1996) estimates dam removal and full restoration of the river would result in 500,000 more visitor days to the area per year from U.S. residents alone, with associated expenditures of $43.8 million per year. These expenditures were expected to support 446 additional jobs in the county.

Non-Market Values

Using a survey technique called contingent valuation, Loomis (1996) estimated the American public would be willing to pay approximately $5.3 billion per year to remove the dams and restore the Elwha River. This number is orders of magnitude greater than other monetary benefits, such as from tourism or increased fishing, but it is not unusual for environmental considerations of national importance. For example, a contingent valuation study of the Exxon-Valdez oil spill in Alaska estimated the American public would be willing to spend $4.8 billion to avoid another oil spill like Exxon-Valdez (Carson et al. 1992).

This technique, commonly used by federal agencies to measure the benefits of projects with substantial environmental impact, involves asking survey respondents to vote yes or no to dam removal if dam removal meant the respondent had to pay higher taxes. By aggregating responses from respondents around the United States, Loomis was able to estimate the American public's value for removing these dams.

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EDWARDS DAM, KENNEBEC RIVER, MAINE

Overview

The Edwards Dam, removed from the Kennebec River in 1999, resulted in significant benefits for recreational fisheries and boating, improved water quality and wetland habitat, and enhanced quality of life for nearby communities. Due to the potential for large ecological benefits and cost savings compared to installing fish passage, this dam removal was the first instance when FERC overrode the relicensing request of a dam owner.

Dam Removal Process

The Edwards Dam, originally built in 1837, was a 917-foot-long, 24-foot-high hydroelectric facility with a relatively small generating capacity of 3.5 MW. The reservoir behind it covered 1,000 acres and extended more than 15 miles up the Kennebec River (FERC 1997, Lewis et al. 2008).

As a hydroelectric project, the Edwards Dam operated under a FERC license, which, along with eight other dams on the Kennebec River, was set to expire in 1993. In their relicensing application, the Edwards Manufacturing Company proposed to expand the generating capacity of the facility from 3.5 MW to 11 MW (FERC 1997).

After an extended regulatory battle, during which FERC overruled the dam owner's preferences to keep the dam in place, the agency ordered the dam to be removed.

Primary Benefits

Recreational Fisheries: Dam removal benefitted recreational anglers through improved catch rates.

River Recreation: Removing the dam opened a new stretch of river, projected to attract many new boaters, while generating $397,000 to $2.7 million in new income.

Property Values: The river is less prone to flooding and water quality is higher, making the river more appealing and increasing property values for those living closest to the river.

Cost Effectiveness: Removing the dam was less expensive than installing fish passages.

Water Quality: Eliminating the dam increased the river's water quality within two months from Class C to Class B.

Commercial Fisheries: Dam removal opened access to more than 17 miles of historical habitat for multiple Kennebec River fisheries.

Quality of Life: The free flowing river created a new amenity for the city of Augusta, the state's capital, with a large new park, and access to new river recreation opportunities.

The dam cost $10.9 million to remove, compared to the $14.9 million needed to build fish passages and perform other environmental remediation (FERC 1997).

Benefits of Dam Removal

Removing the Edwards Dam generated benefits related to recreational angling, boating, property values, cost effectiveness, water quality, commercial fisheries, and quality of life for nearby residents.

Recreational Fisheries

Boyle et al. (1991) estimated recreational anglers' willingness-to-pay (WTP) to restore Kennebec River migratory fisheries and the subsequent improved catch rates. The study estimated recreational anglers would be willing to pay $2.5 million per year for improved fisheries.

Using alternative methods, Freeman (1996) estimated that dam removal would bring a minimum of $2.7 million in annual benefits to recreational anglers. Freeman's findings, and methodological insights highlighting the need to consider benefits other than those related to hydroelectric power, ultimately influenced FERC's decision to deny the dam owner's relicensing application.

Research conducted after the dam was removed used a travel cost model to estimate benefits of dam removal to recreational anglers. Based on average fishing licenses sold in Maine, Robbins (2006) estimated total annual economic benefits of more than $38.2 million between freshwater ($11 million) and tidal water ($27.2 million) sections of the Kennebec.

River Recreation

The U.S. Fish and Wildlife service commissioned Industrial Economics to estimate the benefits from improved boating on the Kennebec River as a case study for its handbook on methods for conducting economic analyses of hydropower project relicensing. This study estimated annual benefits of between $397,000 and $2.7 million, amounting to benefits totaling $4.9 to $61.2 million over 30 years. The wide range in benefits is due to different underlying assumptions about predicted changes in the number of new boaters. At the time of this study, as a point of comparison, the estimated cost of removing the Edwards Dam was $4 million (Black R et al. 1998).

Property Values

After the dam was removed, Lewis et al. (2008) estimated the economic impact of dam removal on property values, the first study of its kind. The report found that properties closer to the Kennebec River had lower property values than properties farther away, potentially due to lower water quality or flooding risk. After dam removal, however, the "penalty" decreased significantly from $2,889 to $194, showing that dam removal has had a small but consistently positive impact on nearby property values.

Cost Effectiveness

In addition to the monetized benefits of dam removal, FERC determined that dam removal would be the least expensive management alternative. Regulators deemed that fish passage was necessary, but installing these structures would make the relicensing option approximately 1.4 times more expensive than dam removal (FERC 1997).

Additionally, electricity produced by the Edwards Dam, under both the 3.5 MW and 11 MW scenarios, cost four to five times the average market rate (FERC 1997, American Rivers et al. 1999).

BEFORE

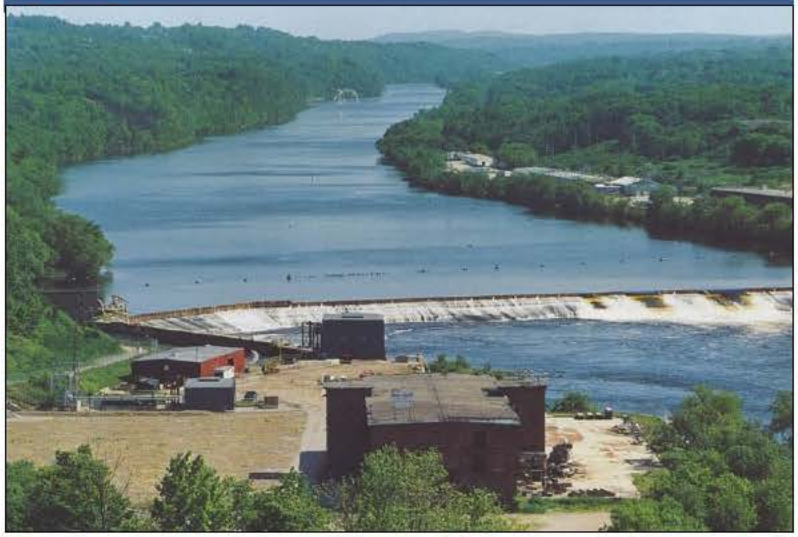

Photo credit: American Rivers

AFTER

Photo credit : American Rivers

Water Quality

Water quality improved quickly and measurably after the dam was removed. Before removal, water in the impoundment behind Edwards Dam failed to meet the minimum water quality standard for Maine (Class C, the lowest standard that supports all native fish). Two months after removal, water quality had improved enough to meet Maine's Class B standard, which indicates the habitat for native fish is unimpaired (Kennebec Coalition 2000).

Commercial Fisheries

In combination with other restoration efforts, removal of the Edwards Dam opened 17 miles of habitat, leading to substantial gains for some of the Kennebec River migratory fish. According to the Natural Resources Council of Maine, the largest runs of alewives and river herring on the eastern seaboard are found in the Kennebec River (Edwards 2014). In 2016, an article in the Portland Press Herald reported that an estimated 3 million alewives now travel up the river annually as compared to a decade ago when fewer than 50,000 did. The species is now being used for commercial fishery bait and has also supported a substantial increase in bald eagles in the area—as the species' annual run coincides with breeding season for the bald eagles (McGuire 2016).

Quality of Life

The City of Augusta, which initially opposed removal due to the losses in revenue and property taxes associated with dam removal, is benefitting from its new connection to the free flowing river, including a 17-acre park where the dam was once located. Mayor Roger Katz noted: "The breaching of the dam is leading to so many wonderful consequences for our community. From the Mill Park with its canoe and kayak launch and new pavilion to the looming Arsenal project, to our expected development of the old paper mill site, we are finally returning our focus to the river" (Fahlund 2016).

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CONDIT DAM, WHITE SALMON RIVER, WASHINGTON

Overview

The Condit Dam, removed from the White Salmon River in Washington in 2012, used to block 12 miles of spawning ground for salmon and 33 miles of spawning grounds for steelhead, including several populations listed under the Endangered Species Act. Removing the dam was the most effective and least expensive means of achieving fish management goals.

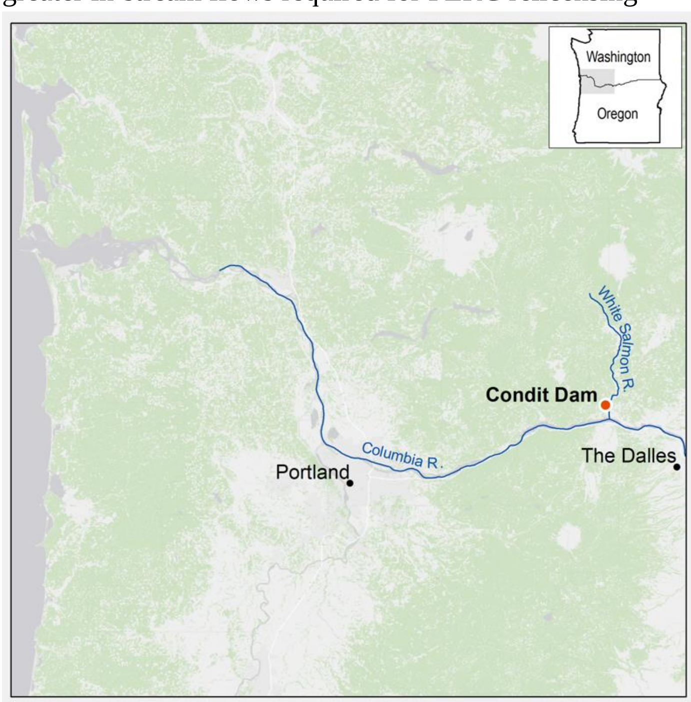
Dam Removal Process

The Condit Dam was a 125-foot-high and 471-foot-long concrete structure located on the White Salmon River in south-central Washington approximately 3.3 miles upstream of the White Salmon's confluence with the Columbia River. A few miles above the dam, the White Salmon is part of the National Wild and Scenic Rivers system. Below the former dam site the river is part of the Columbia River Gorge National Scenic Area (Allen at al. 2016).

The Northwestern Electric Company (now PacifiCorp) originally installed this 14.7 MW hydroelectric facility in 1968 to supply electricity to the Crown Willamette Paper Company in Camas, Washington and support increasing demand from local municipalities (PacifiCorp 2011).

The Condit Dam had no fish passage facilities, creating a barrier limiting migratory fish spawning grounds to the short stretch of river below the dam. To rectify this problem, FERC presented a series of recommendations and an analysis of dam removal benefits and alternatives in a Final Environmental Impact Statement (FEIS) in 2002 (FERC 2002).

PacifiCorp removed the Condit Dam after determining that the modifications to accommodate fish passage and greater in-stream flows required for FERC relicensing



Primary Benefits

Cost effectiveness: Removing the dam was less expensive than installing fish passages.

Cultural: The free-flowing river restored the river and historical fishing grounds important to the Yakama Nation.

Recreational and Commercial Fishing: Without the dam, salmon and steelhead now have access to historical habitat.

Vulnerable Species: Dam removal opened the river to five threatened species including steelhead, Chinook salmon, and Coho salmon.

River Recreation: The river now has five additional miles of boatable whitewater.

would have reduced the dam's energy production, increased production costs, and made continued dam operations uneconomical (FERC 2002).

FERC accepted the dam removal agreement in 2010, the dam was breached in 2011, and dam removal was completed in 2012.

Benefits of Dam Removal

Researchers identified four primary categories of benefits from removing the Condit Dam: cost-effectiveness, endangered species, river recreation, and cultural values. While researchers did not estimate dollar values other than those associated with cost-effectiveness, their importance factored significantly into the decision to remove the dam.

Cost Effectiveness

The primary economic evidence supporting dam removal was the relative cost of removing the dam according to the dam removal agreement ($24.8 million) versus installing the recommended modifications ($52.4 million). Additionally, the reduced generation capacity would have raised generation costs by $48 per megawatt hour, resulting in $3.9 million additional costs for ratepayers (FERC 2002).

Cultural Values

Dam removal has had "profound spiritual and cultural significant for the Yakama Nation" (USFWS 2016). In addition to being a large part of their oral traditions, the White Salmon River and its fish (particularly salmon and lamprey) provided sustenance for tribal members. While much of the post-removal research has focused on salmon, in 2016 Pacific lamprey were found for the first time in more than 100 years in the river upstream from the dam site (Pesanti 2016).

Recreational and Commercial Fisheries

Removing the dam was expected to increase and improve migratory fish habitat, subsequently increasing fish populations and benefitting recreational and commercial fisheries.

Historically, the White Salmon River served as spawning grounds for a variety of salmon and steelhead species. However, without any provision for fish passage the dam blocked access to 12 miles of spawning grounds for salmon and 33 miles of spawning grounds for steelhead (Gimblett et al. 2015). This essentially limited these migratory species to 3.3 river miles below the dam. In addition to removing this major barrier to fish passage, dam removal improved spawning habitat, water quality and instream flow above and below the dam (FERC 2002).

Researchers have studied the river and its fisheries since removal of the dam and have found that the expected increases in fish populations that researchers anticipated are occurring. Fish are creating new spawning grounds, with salmonids using spawning grounds both downstream and upstream of the dam site; some species' spawning counts are increasing and other species are spawning in new locations (see Allen et al. 2016, Hardiman and Allen 2015, Gimblett at al. 2015, Hatten et al. 2015).

Additionally, the FEIS noted, "removal of the Condit dam would provide substantial long-term benefits to the scenic area and scenic river management objectives of the area" (FERC 2002), consistent with its National Scenic Area and Wild and Scenic River designations.

Vulnerable Species

BEFORE

Photo credit: Thomas O'Keefe

AFTER

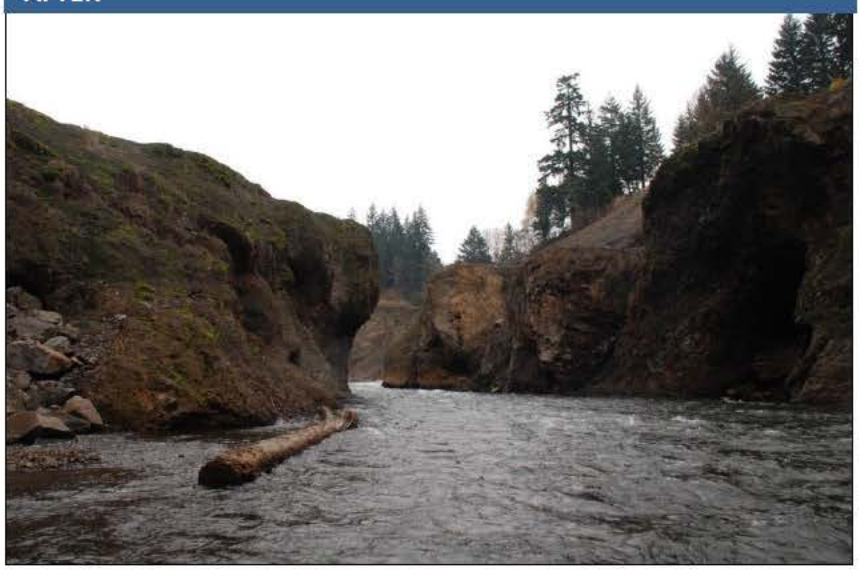


Photo credit: Thomas O'Keefe

The Condit Dam removal project also was expected to support the populations of five fish populations listed under the Endangered Species Act, including sockeye salmon, Chinook salmon, Coho salmon, Chum salmon, steelhead, and bull trout (Hardiman and Allen 2015).

One year after the dam was removed, researchers found redds (places where salmon and steelhead lay their eggs) from both Chinook runs and steelhead above and below the dam (Engle et al. 2013).

Pacific lamprey, a federal Species of Concern, have been found upstream of the dam site for the first time in more than 100 years (Pesanti 2016).

River Recreation

Without the dam, whitewater recreationalists now have access to an additional five miles of river in an area that was already a whitewater destination and important economic driver (FERC 2002, Gimblett et al. 2015). The FEIS also projected that dam removal would result in increased recreational spending in the area as a result of both improved fishing and whitewater rafting/kayaking opportunities (FERC 2002). Research has estimated a low estimate of 30,000 whitewater recreationalists using the White Salmon River during the four summer months of 2014 (Gimblett et al. 2015). The author describes this as "high levels of use" as compared to estimates on other popular rivers. These benefits were not monetized.

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GREAT WORKS AND VEAZIE DAMS, PENOBSCOT RIVER, MAINE

Overview

Removing the Great Works and Veazie Dams from the Penobscot River in Maine in 2012 and 2013, respectively, restored access to nearly 1,000 miles of historic habitat for eleven severely depleted migratory fisheries, including endangered species and culturally and recreationally significant species. This dam removal project, which also included installation of fish passages at the Howland Dam, was the first of its kind to balance the interests of river restoration with hydropower generation, allowing the dam owner to maintain its overall hydropower generating capacity in the region by increasing permitted capacity at other facilities.

Dam Removal Process

The Veazie Dam was a run-of-river hydroelectric facility on the Penobscot River in Maine. It was 32 feet high, 830 feet wide, and had 8.4 MW generating capacity. It was located approximately 25 miles upstream of where the river meets the Atlantic Ocean and was the lowermost impoundment on the river. The Great Works Dam, eight miles upstream of the Veazie Dam, was 20 feet high, 1,426 feet wide, and had 7.9 MW generating capacity.

The dams were removed because research demonstrated that fish passages would not be sufficient to restore the fisheries (Kleinschmidt Associates, 2008).

In 2004 a variety of state and federal agencies, private organizations, and the Penobscot Indian Nation signed a multi-party settlement agreement with PPL Corporation, the owner of the Veazie Dam. The purpose of the agreement was two-fold: 1) to restore access to almost 1,000 miles of historic habitat for “severely depleted” sea-

Primary Benefits

Dam Removal Economic Impact: The dam removal project generated $3.6 million from 76 temporary jobs associated with the project, plus ongoing jobs associated with river recreation and canoe or kayak racing.

Vulnerable Species: Removing the dam opened access to 1,000 miles of historical habitat for 11 sea-run species, including ESA-listed species like Atlantic sturgeon and Atlantic salmon.

Cultural Values: Dam removal restored the river and historical fishing grounds important to the Penobscot Indian Nation.

River Recreation: Since the dams were removed, this section of river has become a boating destination.

run fisheries; and 2) to allow PPL to increase hydropower generation at other approved facilities in Maine to maintain a similar level of total output.

To ensure that PPL Corporation's net power generation goals were met, negotiations to remove the Veazie Dam were done concurrently with negotiations to remove the Great Works Dam, install a fish bypass at the Howland Dam, and increase generation at other Penobscot River facilities. Because PPL increased its generation capacity at other dams, the removal avoided costs to the company or consumers associated with decreased production (Kleinschmidt Associates 2008).

The total cost of buying and removing the dams was estimated to be approximately $65 million (Carpenter 2012). Individual costs to remove each dam ranged from $5.1 to $6.2 million (FERC 2010).

Benefits of Dam Removal

Researchers identified four main types of benefits associated with removing these dams: additional jobs, endangered species, cultural values, and river recreation. Because fish passages were deemed insufficient to restore the fisheries, costs of installing fish passages at the Veazie and Great Works Dams were not considered.

Dam Removal Economic Impact

Research prior to dam removal estimated that removal of the Veazie Dam would create 76 temporary jobs in the area, with a total direct economic benefit of $3.6 million (FERC 2010).

Vulnerable Species

Removal of the Veazie Dam, along with removal of the Great Works Dam and the addition of fish passage around Howland Dam, opened access to 1,000 miles of habitat for eleven "severely depleted historic sea-run fisheries in the Penobscot River system" (Harvey 2014). According to NOAA (2016), these changes provided access to 100 percent of historic habitat for four species—two federally listed under the Endangered Species Act (ESA) (Atlantic and shortnose sturgeon) and two "important recreational species" (Atlantic tomcod and striped bass). Among the other species expected to benefit were the Atlantic salmon (also ESA listed), alewife and blueback herring (both Species of Concern), American shad, rainbow smelt, sea lamprey, and American eel (Kleinschmidt Associates 2008).

Since dam removal researchers have measured the following changes in fish populations:

- Sea lampreys increased from 2,330 in 2012 to 8,333 in 2016 (Holyoke 2012, Maine DMR 2016);
- Alewives and river herring increased from approximately 13,000 in 2013 to 590,000 in 2015 (Miller 2015, Maine DMR 2016);
- American shad increased from an estimated 20 prior to dam removal to 1,800 in 2015 and 7,846 in 2016 (Miller 2015, Maine DMR 2016); and
- The ESA-listed shortnose sturgeon was also sighted for the first time in more than 100 years in the area above the former site of the Veazie Dam (NOAA 2016).

Cultural Values

The cultural benefits of dam removal to the Penobscot Indian Nation, who have lived in the area for more than 10,000 years, are significant. The river and its fish are at the heart of their culture, and their oral history tells of river salmon and other fish being transformed into first Penobscot people (Toensing 2013). The tribe historically relied on the river for sustenance fishing but had been unable to exercise those rights for more than 100 years. At the breaching of the Veazie Dam, Penobscot Chief Kirk Francis stated: "This river is simply who we are. It's the very core of our identity as a people and it's simply the most important thing in the Penobscot Nation's life" (Toensing 2013).

River Recreation

Since the Veazie and Great Works Dams have been removed, this section of the Penobscot River has been used for a variety of boating events, including the Penobscot River Whitewater Nationals Regatta held by the American Canoe Association in 2015, 2016, and to be held there again in 2017 (Miller 2015). These events bring valuable tourism dollars to the nearby communities. In 2014, the Penobscot Indian Nation also hosted the inaugural Bashabez Run Canoe and Kayak Race, which is now in its third year. The economic impact of these additional visitors has not yet been measured.

BEFORE

Photo credit: Steve Shepard, U.S. Fish and Wildlife Service

AFTER

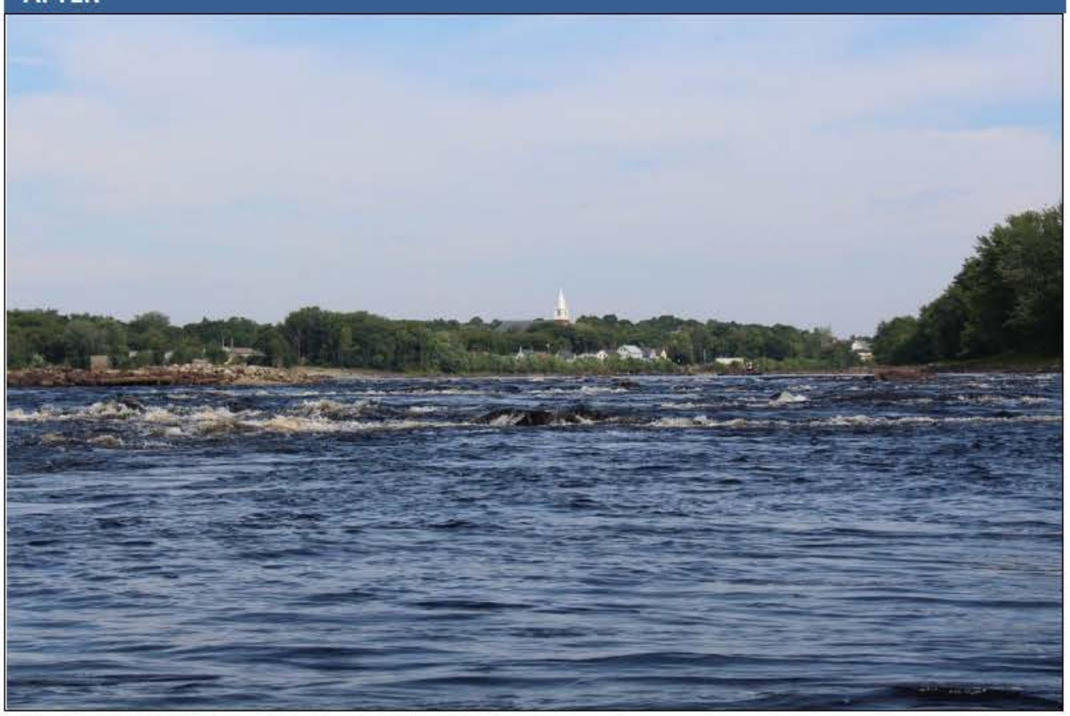

Photo credit: Penobscot River Restoration Trust

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SMALL DAMS CASE STUDIES

Overview

This case study describes the removal of three small dams with similar characteristics. All three privately owned structures were originally built to power small mills, but were no longer used for that purpose at the time of their removal and had fallen into disrepair over time. They also posed substantial public safety risks primarily associated with elevated water levels and flooding, and the potential for breaching or catastrophic failure. All three dams were high enough to prevent fish from moving upstream and none had acceptable fish passage facilities.

Hyde Pond Dam, Whitford Brook, Connecticut

The Hyde Pond Dam on Whitford Brook near Mystic, Connecticut, was a privately owned structure in Connecticut. Originally built in the early 1800s for hydropower, the dam had not been operation for some time before removal in 2015.

Hyde Pond Dam was structurally obsolete and posed a significant public safety risk. Removing the dam opened four miles of stream to important migratory and resident fish species, including alewife, blueback herring, and American eel, candidate species under the Endangered Species Act.

A 2015 Environmental Assessment conducted by the USFWS considered various project alternatives, with a focus on dam removal, the primary purpose of which was to "mitigate flooding and possible dam failure" (USFWS 2015). Removal was funded by USFWS using a $1.1 million grant from federal Hurricane Sandy recovery funding (Federal Grants 2016).

The "no-action" alternative reviewed by the USFWS (2015) stated that the Hyde Pond Dam was in poor condition and was not maintained to regulatory standards, making dam

Primary Benefits

Public Safety: The three dams posed a threat to public safety from upstream flooding and risk of catastrophic failure due to disrepair.

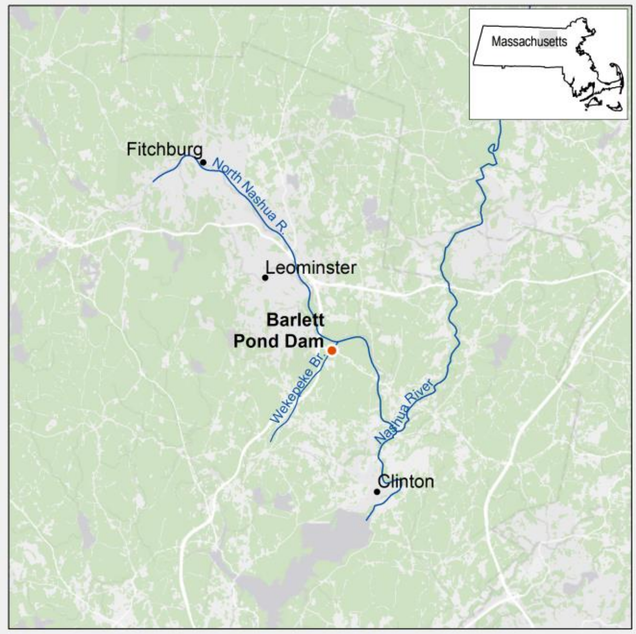
Cost Effectiveness: All three dams would have been much more expensive to repair than to remove. Funding was available from federal and other sources to support dam removal, but dam repair would have been borne by the owner alone.

Vulnerable Species: Removing these dams extended the habitat of migratory and resident fish by numerous miles, including several fish that are candidates for Endangered Species Act listing, including alewife, blueback herring, and American eel.

repair essentially the same as the "no-action" alternative. While funds were available for removal, the owner would be responsible for repairs and future maintenance as well as legal liability in case of dam failure.

Removing the Hyde Pond Dam provided local benefits in the form of increased public safety and restored riverine habitat. It also provided broader regional benefits by mitigating potential flood hazards and supporting coastal resiliency.

Bartlett Pond Dam, Wekepeke Brook, Massachusetts



The Bartlett Pond Dam on Wekepeke Brook in Lancaster, Massachusetts was in poor condition and classified as a "significant hazard," meaning "dam failure could result in loss of life and considerable damage to property or infrastructure" (MDFG 2015). The 2014 removal of the dam also opened 18 miles of river habitat for brook trout and other species.

Bartlett Pond Dam was built in 1814 to provide hydropower for a local chair factory. After the factory burned, the dam was no longer used for power nor maintained. The Town of Lancaster assumed ownership of the dam at some point and incorporated the impoundment behind the dam into a conservation area.

In recent years, obstruction of water flows by the dam had led to multiple floods. In 2008, after a required inspection of the dam, the Town of Lancaster was issued a notice of failure by the Massachusetts Office of Dam Safety. In Massachusetts the law requires that "dams be repaired or removed to meet dam safety standards," meaning that in this case, the no-action alternative was the same as dam repair (MDFG 2015).

The estimated cost of removing the Bartlett Pond Dam was $325,000 compared to $671,000 for repair.

In addition to the cost savings seen by the dam owner, the primary benefits of removing the Bartlett Pond Dam were avoided costs associated with decreased risk of flooding including avoided infrastructure damage, lost business revenue and travel delays.

White Rock Dam, Pawcatuck River, Connecticut and Rhode Island

Before removal in 2015, the White Rock Dam spanned the Pawcatuck River between Stonington, Connecticut and Westerly, Rhode Island. It was structurally and functionally obsolete and posed a risk to public safety. The removal also opened 25 miles of river habitat to key aquatic species, including some ESA candidate species, as only approximately 15 percent of fish were able to navigate successfully the sluice around the dam (Kuffner 2015).

The last version of the White Rock Dam was constructed in 1940 to provide power to a local mill, although dams had been in that location since 1770. At the time of removal, the privately owned dam had not been used for hydropower in decades. In addition to safety concerns, the dam also contributed to elevated water levels and local flooding and was the first impediment to fish moving up the Pawcatuck River.

USFWS conducted an environmental assessment of the dam in 2015 with a recommendation for removal. Federal funding was available for dam removal, but not for repair or maintenance. As such, the private owner would have been responsible for continued maintenance of the structure as well as any cost associated with breaching or failure of the dam.

Removal was funded by USFWS using federal Hurricane Sandy recovery funding and cost an estimated $800,000. This removal was part of a larger $2.3 million restoration effort on the Pawcatuck (USFWS 2014).

In addition to providing cost savings to the owner, removal of the White Rock Dam helped restore access to river habitat for American shad, alewife, and American eel; improved river connectivity; reduced flood risk; and eliminated risk of dam failure.

Bartlett Pond Dam

BEFORE

Photo credit: Massachusetts Division of Ecological Restoration

AFTER

Photo credit: Pare Corporation. For additional details: http://blog.parecorp.com/?p=1124.

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HEADWATERS ECONOMICS

SMALL DAM REMOVAL

A Review of Potential Economic Benefits

TROUT UNLIMITED

Small Dam Removal

A Review of Potential Economic Benefits

TROUT UNLIMITED

October 2001

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ISBN 0-9711699-1-8

This document was prepared with financial support from:
The National Park Service Rivers, Trails, and Conservation Assistance program
The Coldwater Conservation Fund

The views expressed in this document are those of the authors and do not necessarily reflect the views of the funders.

Trout Unlimited is the nation's largest trout and salmon conservation organization. Trout Unlimited's volunteers and members, 130,000 strong, are committed to conserving, protecting, and restoring North America's coldwater trout and salmon fisheries and their watersheds. Trout Unlimited advocates for the selective removal of old, unsafe, and uneconomical dams that are causing more harm than good. Many of Trout Unlimited's volunteers have been actively involved in local projects to remove small dams for the purpose of habitat restoration. For more information, visit www.tu.org or call (703) 522-0200.

Rivers, Trails, and Conservation Assistance (RTCA), a program of the National Park Service, assists local communities and citizen groups revitalize nearby rivers, preserve valuable open spaces, and develop local trail and greenway networks. RTCA staff are based in 36 locations to help local coalitions develop strategic plans, bring together neighbors and other stakeholders, identify potential sources of funding, engage the public's imagination and build partnerships to achieve community-set goals. RTCA also provides support to national non-profit groups to compile information to help communities make decisions about local conservation issues. The RTCA webpage is available at www.nps.gov/ncrc/rtca.

Trout Unlimited established the Coldwater Conservation Fund (CCF) in 1993 to conduct and support scientific and economic analysis that advances TU's mission of conserving, protecting, and restoring North America's coldwater fisheries and their watersheds. The CCF is financed through annual contributions of individuals, TU chapters, businesses, and foundations. Donations support a slate of projects that complement TU's annual conservation agenda by providing sound scientific data relating to water quality, instream flows, and the conservation of America's native and wild salmonids. For more information, please visit www.tu.org/members/coldwater_conserv.html.

Cover photo: A stretch of Maine's Kennebec River formerly impounded by Edwards Dam (Trout Unlimited photo).

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Preface

Blockages in rivers and streams hinder the natural functions of flowing water, and can be especially damaging to fisheries and water quality. As an advocate for trout and salmon, Trout Unlimited (TU) has been working to lessen the impacts of dams on America's streams for more than 40 years.

As fragile species needing high water quality, trout and salmon are often considered indicators of watershed health. They require clean, cold water and connectivity between different river habitats for different needs over their life cycles. Migratory salmon particularly need connectivity to travel from the ocean to reach spawning grounds in smaller tributaries. Dams not only fragment this connectivity, but water sitting still in the sun behind dams can warm to a point where trout and salmon can no longer survive. In addition, many small dams built on rocky bottomed areas with fast moving water have destroyed spawning habitat for these species.

Recognizing that dams can and do provide important societal benefits, TU volunteers and professional staff work with dam owners and regulatory agencies to lessen the impacts of economically viable hydropower dams across the nation. As a result, many dams are becoming more "fish friendly" with minimal impact on power generation, and power companies have more clearly defined operating procedures for the 30 to 50 year life of their operating licenses.

However, many dams — especially smaller ones more than 50 to 100 years old — no longer serve the purpose for which they were intended. Thousands of these old structures nevertheless continue to impede the natural functions of flowing water, and their harmful impacts worsen over time.

While changing societal needs have reduced the need for many of the older, smaller dams, they are also placing more value on clean water, healthy and intact ecosystems, and water based recreation, such as angling and paddling, which benefit from free flowing rivers. As societal values change, so do the economic values associated with them.

TU volunteers and professional staff continue to be at the forefront of growing efforts to restore fisheries and water quality through the selective removal of small dams. We are encouraged that fisheries and other environmental and public benefits are increasingly a part of the equation when a dam owner — often a local community — considers the future of their dam and its host river. But in the majority of cases where there has been a decision to remove a dam, the discussion was prompted by public safety concerns and the final determinant was, and continues to be, economic factors.

Our goal in writing this publication is to draw on current research and TU's experiences with small dam removal to help improve local decision making processes by providing insight into some of the potential economic benefits associated with restoring fisheries and river health through the selective removal of small dams.

This report is not intended to be an in depth economic analysis of dams and dam removal. Rather, it highlights many of the economic benefits that can arise from removing small dams.

While researching this report, it became decidedly evident that there is very little published research on small dam removal, particularly on its economic ramifications. One notable need for additional research is quantifying the effects of small dam removal on nearby land values and on local businesses, along with timescales of these effects. The results of such research would inform and thereby enhance decision making processes. We have laid a foundation for some of this research throughout this report and appendices.

We believe that when small dam removal is considered on its merits, more dam repair/removal discussions will end with decisions to remove dams and restore the natural functions of flowing water — benefiting not just the fish, but the people and businesses of surrounding communities for generations.

Dams and Dam Removal: An Introduction

Dams provided the energy that made the early devel opment of our nation possible. Especially in the Upper Midwest and Northeast United States, nearly every community grew up around a small dam that provided mechanical energy for milling and later generated hydroelectric power.

But many of our country's millions of small dams have become obsolete, victims of society's changing needs and the natural pressures of time, gravity, and rushing water.

Dams are the most visible of human impacts on rivers. Chances are, if someone once determined a site was economically viable for a dam, one was built there. According to one government estimate, roughly 2.5 million dams have been constructed throughout the United States.[1]

The nation's dams run the gamut from tiny struc tures over which one could step, to behemoths that harness our great Western waters. While there are many precise definitions of what a "dam" is, this report refers to dams as any structures that obstruct the flow of water across the width of a river or stream. Some agencies and organizations refer to the smallest of these structures as weirs.

According to the National Inventory of Dams, an inventory maintained by the U.S. Army Corps of Engineers along with other federal and state agen cies, about 75,000 U.S. dams are large structures.[2] The majority of these large dams continue to provide important societal and economic benefits.

The planned life expectancy of a dam is commonly around 50 years, although a well designed and main tained structure can last longer.[3,4,5] Many of the oldest dams were not constructed with a meaningful consideration of life expectancy and many of these dams are no longer around (see sidebar below). Older dams were typically built out of timber and rock or

Dams Can Degrade Over Time

Natural wear, especially the pressure of water, can degrade concrete structures. Without proper maintenance, these structures can fail abruptly during floods or even without a major precipitation event (known as a "sunny day" failure).

Bringing old dams up to today's safety standards can be very expensive. Often removing them is far less costly, and eliminates both safety hazards and expenses for future maintenance.

Structural cracks in Woolen Mills Dam in Wisconsin caused it to fail a 1980 safety inspection. It was removed in 1988 (photo courtesy of Wis. DNR).

Deteriorating concrete on Ontario Dam in Wisconsin resulted in a failed safety inspection in the late 1980s. It was removed in 1992 (photo courtesy of Wis. DNR).

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mounds of earth. Many of these fell into disrepair; were often abandoned and quietly disintegrated.

Others were rebuilt with concrete and repaired or maintained for decades. When they no longer pro vided economic benefits to their owners, many were abandoned.

Today, obsolete dams — some over a century old — are placing economic burdens on owners struggling to bring these structures up to today's public safety standards. Many dam owners are small communities that are now or soon will be looking for financial help to make these repairs.

Even as obsolete and expensive to repair dams con tinue to degrade, the economic and environmental benefits of healthy, free flowing rivers are becoming more well known. In recent decades, scientists have developed a clearer understanding of the far ranging impacts of dams on rivers (Table 1).

Resource managers and conservationists today view selective removal of small dams as one of the simplest and most cost effective methods of restoring natu rally functioning rivers and fisheries (Table 2).

Table 1. How Small Dams Can Ecologically Harm Rivers and Streams

Impair water quality

- Increase water temperatures
- Decrease water oxygen levels
- Block or slow flushing river flows that can normally serve to dilute some pollutants

Obstruct passage

- Block or inhibit upstream and downstream fish passage
- Obstruct the movement of sediment, woody debris, and nutrients

Harm habitat

- Inundate wildlife habitat
- Alter timing and variation of river flows

Trout Unlimited, 2001

A recent report by Trout Unlimited, American Rivers, and Friends of the Earth identified more than 465 dams that have been removed in the past cen tury. Many of these were removed at the dam owner's initiative. *Dam Removal Success Stories* shows that dam removal is not a new or radical notion. The National Park Service, for example, has removed more than 100 dams in the past 20 years on rivers and streams affecting our national parks. Most of these dams were owned by the National Park Ser vice and removed because they were not essential to the use of the park and were not being maintained.[6]

While the concept of dam removal is not new, to a community that grew up around a dam it is usually a new idea to consider removing it. Typically there is strong sentimental attachment to a dam and its impoundment, and many times there is no one alive who remembers the river before there was a dam.

For these and other reasons, discussions about the future of a local dam are often emotionally charged and highly divisive. Many such discussions end with a decision to keep an old and obsolete structure — often at great cost to the river and the community.

But in cases where communities have opted for removal, public safety and economic factors have topped the list of reasons.

Typically, public safety concerns are triggered when a dam fails a safety inspection and a regulating agency orders its repair or removal. Small dam repair costs are often more than three times greater than removal costs.[7] While costs can vary significantly, a dam repair bill for a small dam can easily run $300,000 or more — a high price tag for a small community or individual dam owner.

When decision makers are required to make a fis cally prudent decision, the commonly higher cost of repair alone is often enough to tip the scale in favor of removal.

Nonetheless, many communities faced with the repair/removal question have simply looked for repair money without considering removal as a viable option.

In recent years, however, citizen groups and resource managers have become increasingly successful in persuading communities or other dam owners to consider the merits of all options, including removal.

Table 2. Illustrated Benefits of Case Studies

All benefits of each river restoration are not included here. The Naugatuck, Baraboo, and Conestoga projects are ongoing and some of their benefits are projected.

State	River	Dam(s)	Economic and Other Benefits of Dam Removal	Page
OH	Chagrin	Chagrin Falls	Cost savings over repair Wetland restoration	9
OH	Little Miami	Jacoby Road	Cost-effective restoration Restored scenic value of free-flowing river	17
WI	Kickapoo	Ontario	Community economic development Cost savings over repair Fisheries improved Paddling opportunities improved	19
WI	Baraboo	3 dams	Potential community economic development Fisheries improved Watershed-wide restoration Restored rapids Cost savings over repair	21
WI	Tomorrow/ Waupaca	Nelsonville	First-class trout fishery restored Potential economic development Historical restoration	25
WI	Apple	Somerset	Community economic development Rapids restored New recreational opportunities	26
CT	Naugatuck	8 dams	Cost-effective water quality improvements Potential community economic development Watershed-wide restoration Fisheries improved	28
PA	Conestoga	17 dams	Cost-effective fisheries improvement Potential community economic development Increased angler income projected Watershed-wide restoration Allowed the return of migratory fish	29
WI	Willow	Willow Falls and Mounds	Scenic waterfall restoration Cost savings over repair Safety hazards removed	32
WI	Milwaukee	Woolen Mills	Community economic development Fisheries improved Safety hazard removed	34

Trout Unlimited, 2001

One university study documented what advocates for healthy rivers and fisheries already know — that dam repair/removal decisions are typically made with incomplete and inaccurate information on envi ronmental and economic factors relating to dams and rivers.[7]

Because the majority of small dam removal decisions are ultimately made for economic reasons, it is unfortunate that comparative economic studies are sorely lacking. Decision makers are often not aware of the potential economic benefits associated with dam removal, including benefits from restored rivers and improved aquatic habitat and water quality.

To help improve this decision making process, Trout Unlimited gathered information and con ducted original research on the potential economic benefits of selective small dam removal to create this report for concerned citizens, resource managers, dam owners, and elected officials.

A review of the literature turns up very few pub lished studies on dam removal economics and none that look at economic impacts using post removal data. Historically, this information has been limited because small dam removals have not been well documented. Today, dam removals are increasingly better documented, providing the potential for valu able analyses in the coming years.

The lack of post removal economic analysis is partic ularly unfortunate in urban settings, where residents are often concerned that property values around an impoundment will dramatically decline after a dam is removed.

To begin to address this concern, Trout Unlimited studied the long term impact of dam removal on property values at the site of the 1988 Woolen Mills Dam removal in West Bend, Wisconsin. At that site, property values have not declined dramatically more than a decade later, contrary to the pre removal fears of local residents and homeowners.

The case studies and tables presented in this report are based on available information. The majority of historic dam removal information comes out of the state of Wisconsin, where more than 70 dams have been removed. The discussion of this information is augmented by firsthand experiences of the authors who have been closely involved in many small dam removals.

The result of this research and experience is a discus sion of a number of economic benefits communities might reasonably expect from restoring a river through small dam removal, including:

- improved sport fisheries,
- increased paddlesport opportunities,
- improved water quality,
- community revitalization, and
- significant cost savings by eliminating the costs of maintaining a dam and its impoundment, both now and in the future.

As thousands of small dam owners and communities across the nation are grappling with aging and obso lete dams and their impacts on rivers, this report aims to assist them with their local decision making processes.

A review of the case studies presented herein shows that the communities enjoying the greatest eco nomic and quality of life gains seem to have some thing in common — they have reconnected with their free flowing rivers through thoughtful plans that include building parks, riverwalks, and boat launches, and providing public access to the restored river.

"Small" Dams and Why They Are Significant

There is no universal specification defining the size of a "small" dam. Some state agencies consider dams less than 15 feet high as small. The National Inventory of Dams (NID) uses a combination of height and impoundment size as a cutoff for inclusion. The NID includes dams that are either 25 feet high with an impoundment of at least 15 acre feet, or six feet high with an impoundment of at least 50 acre feet.[2] (An acre foot is an amount of water that would fill an acre to the depth of one foot). A particular small dam may or may not be regulated by state or federal agencies.

Clearly, "small" is a relative term. This report, which focuses primarily on small dams, discusses the removal of two dams that were around 60 feet high, not so small in the Great Lakes and Northeast, but still small by Western U.S. standards.

Contrary to common belief, most small dams, particularly those originally designed to power mills, do not provide flood control. In fact, some small dams increase upstream flooding problems because they impede flow, but do not have the capacity to store it. There are some small dams that do provide flood control, but such dams are designed with a lot of corresponding area available for storing flood waters. For example, many of the so called PL 566 dams constructed by the Soil Conservation Service (now the Natural Resources Conservation Service) for flood control could be considered small dams.

In addition, hydroelectric dams that produce power for entire regions of the country would certainly not be considered "small" dams. Therefore, this report does not focus on the costs and benefits of flood control or large scale hydroelectric facilities.

Despite their stature, small dams have significant impacts on streams and habitat. Such structures effectively block fish passage and otherwise damage river systems much like larger structures. The age of these structures is also ecologically significant. The longer a dam blocks a river, the more damaging the impact on the stream channel and its habitat. Small dams have fragmented many rivers and streams since colonial times.

Perhaps the most significant impact of small dams is their sheer number. Thousands of communities around the country have small dams. As a result, many rivers and streams are segmented every few miles by a dam. Data included in the National Inventory of Dams (NID) suggest that small dams create three to four times more total reservoir area in the country than large dams.[8] This ratio is likely even higher because the parameters for inclusion in the NID leave out many of the smallest dams. The cumulative impact of these structures and their impoundments can be devastating to rivers and their fisheries. The total effort of maintaining, repairing, or removing the sheer number of structures will be significant in the coming years from economic, environmental, and public policy perspectives.

The impact of dams is especially acute in "headwater" areas where rivers and streams originate. These smaller water bodies, often spring fed coldwater streams (46 to 60 degrees F) that support coldwater species such as trout, are especially sensitive to temperature changes. Water is warmed as it sits impounded behind small dams, hindering the survival of coldwater fish above and below the dam.

In addition to impacts on water quality and fishery health, managing a small dam can become a burden to its owner, often an individual or small community. Safety issues come to the forefront as small dams age, and maintaining dams and their impoundments can become a financial burden.

Economic Benefits of Removing Small Dams

Despite the many environmental and societal benefits that can result from dam removal, discussions about the future of an old dam often boil down to money. How much money has to be spent to either repair a structure or remove it?

Removing a small dam can have distinct economic benefits. Depending on the site, economic benefits could include:

- significant cost savings over repairing and maintaining the dam,
- potential for community economic development through parks, riverwalks, and urban revitalization in and adjacent to the restored stream,
- new opportunities for local recreation and growth in tourism,
- increased income to local fishing and paddling industries, and
- decreased costs related to water quality improvements and fisheries management.

These benefits are not necessarily comprehensive, nor do all benefits mentioned apply to all dam removals.

Repair commonly costs more than removal

Over the past century, more than 465 dams have been removed from rivers and streams in the United States. Many removal situations began when a dam failed a safety inspection and the owner was issued an order to repair, rebuild, or remove it. From that point forward, decisions often hinged on economics.

In most cases, the cost of removing a small dam is less than the cost of rebuilding or repairing it. Add to this the fact that many communities and dam owners have trouble finding the funds to repair and maintain their dams, and it is easy to see why removal is often the only affordable option.

The cost of removing a small dam has usually been much less than the cost of rebuilding or repairing it.

Based on available data from dam removals in Table 3 and using lower end repair estimates, cost estimates for dam repair versus removal from around the country show that repair has averaged three times more expensive than removal (see Chagrin River, p. 9). Of course, project costs can vary significantly and should be carefully evaluated when each new case arises. For example, note the one case on Table 3, Somerset Dam on the Apple River, where removing the dam cost more than repair estimates to make the dam safe.

Repair costs may include structural measures for safety purposes, such as fixing inoperable gates or repairing cracking concrete. In some cases, they may also include improvements to meet current standards for environmental protection, such as adding or improving fish passage.

Note that the values in Table 3 compare only short term removal costs, not future costs for dam operation, ongoing maintenance, repairs, liability, or costs of environmental damage, which could make removal even more cost effective. Also, Table 3 only includes information on dams that have been removed, not on dams that were ultimately repaired. Often when a dam is repaired, removal is not estimated or even considered (see sidebar, p. 11).

While dam owners are generally held responsible for the cost of repairing or removing a dam, often with publicly owned dams repair or removal is funded by taxpayer dollars. As taxpayers, citizens should be aware of how dam decisions are made and how the outcome affects them financially.

Table 4 shows repair and removal costs for 11 dam removal projects in Wisconsin, with costs converted to 1999 dollars for comparison. These projects were not randomly chosen, but were selected based on availability of

Table 3. Removing Small Dams Typically Costs Less Than Repair

A sample of dam repair estimates, dam removal estimates, and actual dam removal costs. Some data are shown as a range, either because the estimates involve several options or because the range reflects the best information available from sources closely familiar with the project.

State	River	Name of Dam (Year Removed)	Estimated Repair Cost ($)*	Estimated Removal Cost ($)*	Actual Removal Cost ($)*
CA	Butte Creek	Four dams (1998)	N/A	9.500.000	9.130.000
CA	Cold Creek	Lake Christopher (1994)	160,0000 - 180,000	N/A	60,000 - 100,000
FL	Chipola	Dead Lakes (1987)	N/A	32,000	32,000
ME	Kennebec	Edwards (1999)	9,000,000**	N/A	2,100,000
ME	Pleasant	Columbia Falls Hydro (1998)	80,000***	N/A	20,000 - 30,000
ME	Souadabscook	Grist Mill (1998)	150,000	N/A	56,000
MN	Cannon	Welch (1994)	N/A	120.000	46.000
MN	Kettle	Sandstone (1995)	1.000.000	300.000	208.000
NM	Santa Fe	Two-Mile (1994)	4,100,000	N/A	3,200,000
WA	Whitestone	Rat Lake (1989)	261,000	N/A	52,000
WI	Baraboo	Waterworks (1998)	694,600 - 1,091,500	N/A	213,770
WI	Willow	Mounds (1998)	3.300.000 - 6.000.000	1.100.000	500.000
WI	Willow	Willow Falls (1992)	5.000.000 - 6.000.000	622.000	450.000
WI	Yahara	Fulton (1993)	900,000- 1,000,000	N/A	375,000
WI	Black	Greenwood (1994)	500,000	N/A	80,000
WI	Embarrass	Hayman Falls (1995)	455,000 - 800,000	N/A	180,000
WI	Lemonweir	Lemonweir (1992)	700,000	N/A	190,000
WI	Manitowoc	Manitowoc Rapids (1984)	30,000 - 250,000	N/A	45,000
WI	Kickapoo	Ontario (1992)	100,000 - 200,000	N/A	47,000
WI	Prairie	Prairie Dells (1991)	725,000	N/A	200,000
WI	Apple	Somerset (1965)	30,000	N/A	75,000
WI	Milwaukee	Young America (1992)	313,000	N/A	74,000
VT	Clyde	Newport No.11 (1996)	783,000	N/A	550,000

* Dollars are assumed to be in the year the dam was removed.

** Cost of installing fish passage.

*** Cost to repair fish ladder.

Removing a Dam *and* Restoring Wetlands at a Fraction of Repair Costs

Chagrin River, Ohio

Chagrin Falls Dam once powered a grist mill on the Chagrin River, a state scenic river in northeastern Ohio. When the dam unexpectedly and catastrophically breached in 1994, a decision was made to remove the old structure as the cost of repairing the dam was estimated at over $1 million.

The actual cost of removing the dam *and* restoring its adjacent wetlands was just over $100,000, *one-tenth* the estimated cost to repair the dam. In addition to the cost savings, the project is significant because it is an example of wetlands establishment in conjunction with river restoration. Riparian wetlands (adjacent to rivers and streams) support diverse wildlife habitat, help alleviate flooding, and filter sediment and pollutants before they reach the stream.

Ivex Corporation, a paper processing company and owner of the dam, donated 80 acres of the former impoundment and surrounding riparian land to the village of Chagrin Falls. This valuable land, now Whitesburg Park Preserve, is located next to land owned by The Nature Conservancy, providing a continuous corridor of protected land along the Chagrin River.

Mudflats, exposed when Chagrin Falls Dam failed in 1994, were converted to riparian wetlands when the dam was removed (photo courtesy of Ohio DNR).

Riparian wetlands along the Chagrin River in Ohio provide diverse wildlife habitat. The wetlands were established along with the removal of Chagrin Falls Dam (photo courtesy of Ohio DNR).

Table 4. Removing Small Dams Saved Millions of Dollars in One State

Repair estimates versus removal costs for 11 Wisconsin dam removal projects. Wisconsinites saved between $6.1 and $10.2 million by choosing to remove these dams rather than repair them, and also restored many miles of free-flowing rivers. Values are converted to 1999 dollars for comparison.

Name of Dam	Low Cost Estimate for Repair ($)	High Cost Estimate for Repair ($)	Actual Cost of Removal ($)
Fulton	1,037,650	1,152,940	432,350
Greenwood	562,080	562,080	89,930
Hayman Falls	497,400	874,540	196,770
Lemonweir	831,220	831,220	225,620
Manitowoc Rapids	48,100	400,870	72,160
Mounds	3,372,880	6,132,520	511,040
Ontario	118,750	237,500	55,810
Prairie Dells	886,820	886,820	244,640
Somerset	158,670	158,660	396,670
Waterworks	709,940	1,115,610	218,500
Young America	371,670	371,670	87,870
TOTAL	**8,595,170**	**12,724,420**	**2,531,350**

Source: Trout Unlimited, 2001 calculated from Born, et al., 1996[9] and Wisconsin DNR dam files.

information. Only one of these dams, Manitowoc Rapids, was privately owned at the time of its removal. The others were either abandoned (which means responsibility fell to the state or local government) or owned by public municipalities or counties. The figures were converted to 1999 dollars to allow for a direct comparison of repair versus removal.

These projects show a sizeable cost savings to dam owners and taxpayers by choosing removal instead of repair.

The estimated total cost of repairs for the dams in Table 4 ranged from $8.6 to $12.7 million. These dams were all ultimately removed at a total cost of just $2.5 million, saving Wisconsinites between $6.1 and $10.2 million for choosing to remove these 11 dams, or about $550,000 to $920,000 per dam on average.

While short term cost figures can indicate the magni tude of cost differences, a true comparison between keeping a dam and removing it requires looking at *all* the costs of each option.

For example, decisions to repair an aging dam — in effect, to keep the dam — often do not include future operation and maintenance costs. Estimates also often omit the cost of environmental damage (such as fishery habitat loss) or mitigation of these damages (such as fishery management costs).

The true cost of owning a dam must include all such expenses, including:

- general operation and maintenance,
- repairs (often multiple over time),
- maintaining the impoundment and its water quality,
- environmental costs (see sidebar, p. 12), and
- liability costs.

Opportunity Cost: The Cost of Making a Decision

Opportunity costs are relevant whenever a decision must be made about using resources for one purpose rather than another. The opportunity cost of a chosen action is the benefit (opportunity) lost by not choosing the next best alternative. It is the highest value alternative that was foregone. The lost opportunity of the next best option is considered a cost of the chosen action.

For example, when a decision is made to use funds to repair a dam rather than remove it, the opportunity for a free-flowing river is lost. So, the benefits associated with a free-flowing river may be the opportunity cost of repairing instead of removing a dam. The opportunity cost could also be an alternative use for the money, such as for road repair, health care, etc. Particularly when environmental costs are considered, money alone may not be the best measure of opportunity cost. While a restored river can provide economic benefits, many of its benefits are difficult to quantify financially (see 'willingness to pay' studies in Appendix II).

Similarly, when dam removal costs are presented to the public, related costs such as stream stabilization are often not included. The cost of removing a dam should include:

- removing structures,
- sediment management,
- associated stream channel work, if necessary,
- ongoing restoration and monitoring costs, if necessary, and
- replacing the dam's use(s), if necessary.

These costs are discussed in detail below.

Repair decisions should consider all costs

General operation and maintenance costs

Small dam operation and maintenance costs vary and typically are not widely publicized. Operation and maintenance refers to the day to day work to operate the structure and to keep it safe and in working order. It includes such things as keeping the gates and other structures operational, maintaining security, maintaining the property and facilities, and liability insurance. A good operation and maintenance plan can help maintain safety and pro long the time before major repairs are needed.

Such costs should be projected for the entire life of the dam. Costs can vary widely even for similarly sized dams depending on location, age, and other fac tors. For example, the estimated annual operation and maintenance costs of the 18 foot high Woolen Mills Dam in West Bend, Wisconsin, were $10,000 per year. Also in Wisconsin, the 16 foot high Ward Paper Mill Dam had annual operation and mainte nance costs of $60,000 per year. The primary differ ence in cost was need for greater security measures at Ward Dam.[12]

Publicly owned dams should maintain clear records of operation and maintenance costs and make them available to the public. Only with accurate information will communities be able to make informed decisions when faced with a dam in need of repair or removal.

Costs of maintaining impoundments

One aspect of small dam maintenance often over looked is the cost of maintaining the dam's impound ment.

An impoundment is the reservoir of water held back by a dam. However, dams not only hold back water, they also trap sediment that would normally be car ried downstream. This sediment collects in the impoundment, gradually filling it in, a process known as sedimentation.

As impoundments fill in, they lose the ability to sup port the uses of the dam and impoundment. The time over which this occurs is determined by such factors as:

Benefit-Cost Analysis: What Is the Value of a Healthy Environment?

Benefit-cost analysis (BCA) is a framework used to assess proposed projects, indicating that a project should be undertaken if its benefits exceed its costs. It was first described in federal legislation in the Flood Control Act of 1936, which justified federal involvement in flood control "if the benefits to whomsoever they may accrue are in excess of the estimated costs."[13] Since that time, BCA has been used by federal agencies and others to assess thousands of projects.

While it sounds like a simple, objective approach, it is often complicated and subjective to assign values to many benefits and costs, particularly concerning environmental issues.

For example, what is a pristine view worth?

What is the extinction of a species worth?

How much is clean water worth?

Even though you may never go fishing in a faraway river, how much is it worth to know that you could if you wanted to some day? Or, that your grandchildren could?

Although placing a value on these things is certainly a challenge, the value of the environment has been included more and more in BCA.

Economists divide the values involved into use and non-use values. A use value is the value of a resource to people using it. A non-use value is the value to people who are not currently using the resource. Non-use values include such things as option values (to experience it in the future); existence values (to know it exists); and bequest values (to know future generations can experience it).[14]

While it is still a challenge, economists have developed surveying techniques to put values on environmental issues. One of these techniques, contingent valuation, is described in Appendix II.

- the size of the impoundment,
- the size of the watershed,
- land use within the watershed, and
- the operation and condition of the dam structure.[15]

Sedimentation reduces habitat for fish and affects recreational uses of the impoundment, such as fishing, boating, and swimming. Nutrients also build up along with the sediment, causing algae and plant life to become overgrown, in a process known as eutrophication. Such silt filled ponds often become aesthetically unpleasant and smell of rotting vegetation.

Dealing with the effects of sedimentation and eutrophication can be costly. Many communities choose to periodically dredge their impoundments to attempt to maintain recreational uses and aesthetics.

Dredging involves using heavy machinery to dig material out of the impoundment and transport it away. Dredging is usually expensive, with costs ranging from $1 to $12 per cubic yard of sediment removed. The relatively wide range reflects different dredging techniques and varying disposal costs of dredged material. Dredging is not a permanent solution because it does not remove the problems that make dredging necessary. Consequently, an impoundment that needs to be dredged will likely need to be dredged again in the future.

Exact dredging cost estimates are difficult to generalize because of site specific conditions. A few examples from Wisconsin show that though dredging costs are variable, it generally costs hundreds of thousands of dollars, even for small impoundments (Table 5). In addition, in areas where upstream land use changes for development or agriculture increase erosion and runoff, dredging needs to be done more often.

Some communities will harvest excessive vegetation from impoundments and lakes more frequently than dredging in order to maintain recreational uses and aesthetics. Such harvesting involves the use of heavy machinery to cut plants and remove them for transport, often to a composting site for agricultural use.[16] While aquatic vegetation harvesting is cheaper than

Table 5. Dredging Impoundments Is Costly

Dredging costs of several impoundments in Wisconsin, selected based on availability of information.

Date	Impoundment	Size of Impoundment (acres)	Sediment Removed (cu. yds.)	Cost ($)
1979	Henry Lake	44	200,000	413,000*
1981	Bugle Lake	35	250,000	191,000
1981	Angelo Millpond	N/A	160,000	260,000
1981	Hartford Millpond	N/A	42,000	394,000
1983	Marinuka Lake	107	500,000	700,000

* includes cost of dredging, and reducing sediment delivery rates

Source: Marshall, 1988.[15]

full dredging, it is often done every year and can amass considerable expenses over time.

Cost of repair

When an aging dam is reviewed for repair or removal, the true cost of repair is often underestimated because future repairs are not considered and immediate repair costs are often underestimated. Project managers often underestimate repair costs because they do not realize the necessary extent of repairs until the work has begun. Also, as with any old structure, when repair workers dig into an aging dam, surprises are common and the dam may be in worse condition than expected. Often, the interior of the dam structure is unknown, as current concrete could be encasing older timber or rock structures.

Maintaining an old dam can mean committing to a continuous stream of expenses.

Maintaining an old dam can mean committing to a continuous stream of expenses. In the long run, repair bills continue to be incurred, whereas removing a dam puts an end to repair costs.

Table 6 shows one example of a series of repair costs on the Little Falls Dam on the Willow River in Wisconsin, a 30 foot high structure built in the 1920s.

Communities should be prepared to pay for current and future costs of repairing and maintaining dams when they choose to continue operating a dam.

Environmental costs of dams on fisheries

Dams cause many environmental problems in river systems (Table 1). They can significantly impact fisheries by harming water quality, blocking movement and migration patterns, and altering habitat and natural river flows. The potential economic value of a restored fishery, as well as the costs of fishery management, should be considered when communities face a decision to remove or repair a dam.

The construction of a dam essentially changes the upstream environment from native riverine habitat to impounded lake habitat. As a result, the number, types, and diversity of aquatic species change.

Many fish species have different needs at different life stages. For example, migratory salmon need swift flowing cold water and gravel beds, shallow tributaries, deep pools, and passage to the ocean or a lake and back at different stages in their life cycle.

Table 6. Aging Dams Can Need Continual Repairs

Selected repair costs on Little Falls Dam on the Willow River, Wisconsin. The dam was built in the 1920s and is 30 feet high and 370 feet long. This is not a comprehensive list of repairs. These items were selected to illustrate types of repairs and potential magnitudes of costs.

Year	Action	Cost ($)	Cost (1999 Dollars)
1980	Major Repairs*	1,000,000	2,021,840
1990	Installed Gate Operators	281,000	358,180
1991	Right Abutment Repairs and Associated Work	386,700	473,010
1996	Flood Warning System	279,000	296,250
TOTAL COST of REPAIRS			**3,149,290**

* included concrete and spillway repairs; new gate operators, bottom sluice, walkway, and fencing

Source: Wisconsin DNR dam files.

Without connectivity between these habitats, they cannot survive. Even non migratory "resident" fish require connectivity for habitat needs throughout the seasons of the year and throughout different lifecycle stages, and to maintain genetic diversity.

Nearly half of the 496 animal species federally listed as threatened or endangered are freshwater species.[17] They are severely impacted by watershed manage ment practices and particularly by dam operations. Millions of dollars are being spent in attempts to restore salmon, shad, and other species across the country as increasing numbers of fish and mussel species dwindle to the point of federal listing or con sideration for listing.

Recognizing that dams block fish movement and migration and that waters and fish are public resources, some regulatory programs require dam owners to install devices that allow fish to pass over or around the dam. Fish passage technology is often not successful for all species and all life stages, and in many cases can be expensive to install and maintain.

The recreational value of fish can be substantial, and many dams are being removed or being considered for removal to restore highly valued fisheries. The economics of fisheries are discussed more extensively in the following pages in sections on sport fishing, trout fishing, and the economic ripple effect.

Safety issues and liability

Another cost of maintaining a dam is the risk associ ated with failure and other safety concerns, such as people boating or swimming near or playing on the structure.

Large dam failures in the United States have been devastating and costly. For example, when St. Fran cis Dam in California broke in 1928, more than 385 people were killed. The 1976 Teton Dam failure in Idaho and the 1982 Lawn Lake Dam break in Colo rado also caused loss of life and resulted in damages of $900 million and $35 million respectively.

According to the Federal Emergency Management Agency (FEMA), "Despite the strengthening of dam safety programs since the 1970s, dams continue to fail, causing loss of life and millions of dollars in property damage."[18] Between 1960 and 1997, 23 dam failures caused loss of life, resulting in 318 deaths.

Damages due to dam failure are not exclusive to large dams. FEMA states, "Failure of even a small dam releases sufficient water energy to cause great loss of life, personal injury, and property damage."[3] A sudden, massive release of water and sediment can also devastate aquatic habitat.

The failure of one dam can also result in subsequent failures downstream. For example, during Tropical Storm Alberto in 1994, more than 230 dams failed in the state of Georgia alone.[18]

While the number of dam failures varies greatly from year to year, the National Performance of Dams Program (NPDP) estimates that on the order of one of every 10,000 dams fails each year.[19] The NPDP notes that failure rates have not been rigorously calculated in many years and that large dams probably fail less frequently than this rate. However, the failure rate of smaller dams is likely higher because small dams are commonly older structures, are often not as routinely maintained, and have less spillway space (where excess water flows) to relieve flood pressure.

Based on NPDP estimates, dam safety costs for America's aging dams will be approximately $1 billion per year for the next 20 years, including such things as costs to upgrade unsafe dams, dam failure costs, and state dam safety program costs.[20]

Dam structures can also be enticing yet dangerous places to play, swim, and boat, so called "attractive nuisances." Small dams can be particularly dangerous for swimmers and boaters because of deceptively dangerous currents over and around the dam.[21] In 1997, a kayaker drowned in Pennsylvania's Kishacoquillas Creek from capsizing and getting stuck in powerful currents at a dam that was only four feet high.[22] Because of the dangers of dams, Pennsylvania recently enacted a law requiring all dams to have warning signs, and dams 200 feet long or longer to have buoys and exclusion zones above and below the dam.

The combined cost of insuring against dam failures and accidents can result in high liability costs. Generally, state and local governments and large dam owners are able to afford the cost of insurance. However, for the largest number of dams, those that are small and privately owned, dam insurance can be prohibitively expensive. Because of the uncertainty of risk, insurance companies charge rates according to worst case scenarios.[3]

The extent of owner liability varies from state to state and can depend on whether the owner is private or public, federal or nonfederal. It can even depend on the design purpose of the dam. For example, the Flood Control Act of 1928 provided that the federal government cannot be held liable for any flood damages relating to any dam authorized for flood control.[23]

In general, government dam owners, from federal to municipal, may be exempt from liability simply from an old common law known as "sovereign immunity." Sovereign immunity provides that governments are exempt from liability unless statutes have waived this immunity. In many states, immunity has been statutorily waived for many circumstances, possibly exposing dam owners to liability from damages or drownings. For example, the Wisconsin Supreme Court abolished sovereign immunity for all Wisconsin municipalities in 1962, although in practice there have been some exceptions to this rule.[24] The issues of liability and immunity for government owners are complex and variable, making it virtually impossible to make blanket statements.

On the other hand, sovereign immunity does not apply to private dam owners, and it is likely that damages caused by a dam failure will lead to extensive litigation[25], exposing the owner to financial risk. FEMA offers financial assistance to owners only when a failed dam is located within a declared federal disaster area.

A National Research Council report on dam safety reports that courts are more often moving to compensate victims, stating that "most courts strain to invoke liability, particularly when personal injury or death is involved."[23]

Removal decisions should consider all costs

Costs of removing structures and restoring the river

Engineers and contractors commonly overestimate the cost of removing small dams. Table 3 shows a few such cases, including two where removal estimates were more than double actual removal costs. Overestimates may occur because of inexperience with dam removal operations. In such cases, contractors and engineers will estimate conservatively to be certain that all their costs will be covered. As more dams are removed, it is likely that increased familiarity will lead to more accurate estimates.

In the simplest cases, small dam removal costs include the costs of heavy equipment and an operator to demolish the dam structure. However, dam removals are often more complex and can include:

- project design,
- removal of structures,
- management of stored sediment,
- stream channel reconstruction or stabilization, and
- disposal of waste materials.

Depending on the size of the impoundment, amount of stored sediment, and the extent of environmental concerns, each dam removal project may not include all of the above measures or may include them to varying degrees or may even include items not listed here. But even when all of the measures are necessary, removal costs are frequently cheaper than rebuilding or repairing an aging structure (see Little Miami River, p.17).

Managing sediment can be the most costly and challenging physical aspect of a dam removal. Dam impoundments are collection areas for material flowing from upstream. Depending on past uses of land within the watershed, they may contain contaminants. Releasing contaminants into the environment or suddenly releasing large volumes of sediment can be damaging to downstream habitat. Sediment management plans should be carefully considered before proceeding with a dam removal, especially if contamination may be present.

Dam removal costs are often overestimated.

Because sediment dredging can be expensive (Table 5), alternative and less costly approaches are often taken, such as collecting sediment in downstream traps or slowly drawing down the impoundment to allow sediment to gradually stabilize.

Depending on the size and topography of the impoundment and the extent of channel restoration work, removing a dam may leave behind exposed, unvegetated banks. Seeding, erosion control matting and other methods are often used to prevent erosion. Depending on the site conditions, bank stabilization can be costly.

As one example based on available information, following the 1992 removal of Willow Falls Dam on Wisconsin's Willow River, bank stabilization costs totaled $370,000.[26] However, many small dams with small impoundments require minimal bank stabilization and little or no revegetation efforts. Former impoundments can be very fertile and full of seeds, which quickly sprout when exposed. New vegetation growth helps to hold the exposed soil in place.

Costs of replacing uses

An important consideration is the cost of uses that will be lost as a result of a dam's removal, some or all of which may need to be replaced. For example, the vast majority of small dams that are considered for removal are not economically viable as hydroelectric facilities. But if a dam does cost effectively produce hydropower, the value of lost power production and the cost of replacement power should be considered in the decision making process.

If a dam is a water supply source, alternative supplies would have to be explored. In addition to agricultural and municipal water supplies, some small dam impoundments are used as emergency water supplies for firefighting. A free flowing river may still produce adequate water for these purposes, but engineers and resource managers should be consulted to determine potential problems and solutions.

While most small dams do not provide flood control, it is an important discussion point in the decision making process. There is a common perception that all dams provide flood control, and the public should be informed about the functions and capabilities of a particular structure when it comes under consideration.

Some impoundments provide "lake" recreation. Surveys can help find the value to the community from tourism and other recreational uses of the lake if that information does not already exist. It is important to look at that information over time, since the quality of impounded water usually declines as it ages and area residents may not be aware of incremental changes.

After generating values for current recreational use of the impoundment, decision makers should also assign values to the potential new habitat and recre ational opportunities created by the restored river system. The various benefits of related community development, improved sport fishing and paddle sport opportunities, and water quality improve ments are discussed in the following pages.

Restoring Scenic Beauty Through Creative Funding

Little Miami River, Ohio

The Ohio Department of Motor Vehicles sells scenic river license plates as an innovative method to fund restoration projects on Ohio's scenic rivers. These sales funded the removal of Jacoby Road Dam from the Little Miami River in 1997 at a cost of $10,000 to $12,000.

Ohio motorists can help preserve natural resources when they purchase license plates. Sales of this license plate fund conservation work on Ohio Scenic Rivers (photo courtesy of Ohio State License Plates).

Identifying available funding sources for dam removal is a task faced by many communities. Possibilities for funding include private, federal, state, and local sources.

Below are some national, regional, and state sources that have funded dam removals (for additional funding possibilities see American Rivers, 2000[27]).

National and Regional Funding:

- US Fish and Wildlife Service—Coastal Program and Partners for Fish and Wildlife
- National Fish and Wildlife Foundation
- National Marine Fisheries Service—Community Based Restoration
- US EPA—Chesapeake Bay Program
- Natural Resources Conservation Service—Wildlife Habitat Improvement Program (WHIP)
- Coastal America Program
- Great Lakes Fishery Trust

State Funding:

- Legislative Appropriations for Dam Removal
- State Natural Resources, Fisheries, or Environmental Protection Agencies
- Dam Safety Programs
- Dedicated Funds for Habitat Improvement, River Restoration, or Fishery Enhancement
- Special Revenue Funds from Fishing Stamps or License Plates
- Environmental Penalty Mitigation Funds

A restored river can be an opportunity for revitalizing a community

"Having a hard time revitalizing your downtown?" questioned a recent Wall Street Journal article, "You may want to consider knocking the dam down."[28] Restoring a river by removing a dam can relieve a financial burden, help a community grow economically, and serve as a catalyst for revitalization.

While some studies have estimated the effects that a proposed dam removal may have on a community, the effects that actually occur after a dam has been removed have not been well documented. Because of this lack of data, it is difficult to make generalizations on the long term impacts of dam removals within communities. Nonetheless, ten case studies throughout this report highlight some of the dam removals that have led to increased economic activity.

> **"Having a hard time revitalizing your downtown? You may want to consider knocking the dam down."**
>
> ***— The Wall St. Journal (Oct. 8, 2000)***

Some communities benefit from the added income brought in when recreation industries capitalize on improved opportunities. For example, canoeing and fishing opportunities improved following the 1992 removal of Ontario Dam on the Kickapoo River (see Kickapoo River, p. 19). Income from these activities has been especially important to the small rural communities in southwestern Wisconsin.

Prior to the removal of Edwards Dam near downtown Augusta, Maine, the Kennebec River was viewed by many as little more than an obstacle separating one part of the city from the other. When the dam was removed in 1999, new fishing and boating opportunities helped the public rediscover the river. Developers, taking notice of the renewed interest, are purchasing properties along the riverfront, speculating that in several years they will be part of a popular riverside downtown area.

It appears that the communities that have realized the most economic benefit from dam removals are those that have specifically developed plans for restoring the river system and revitalizing the community.

More than a decade after the removal of Woolen Mills Dam in West Bend, Wisconsin (see Appendix I), local residents are benefiting from quality of life factors associated with increased recreation in the former impounded area. Local businesses are also benefiting from increased use of the area. The new recreational opportunities were incorporated into the restoration plan guided by input from the community and state natural resources agency. Implementing the plan converted 61 acres of reclaimed land from the impoundment into a park with restored prairie land, ball fields, hiking trails, and access for boating and fishing.

According to a recent survey of area residents, the riverwalk associated with the park received one of the highest approval ratings of any aspect of the city.[29] Local business representatives believe that the quality of life improvement helps them recruit and keep high quality employees.[30]

As another example of revitalization planning, the community of Baraboo, Wisconsin, received financial assistance from the state in the form of a planning grant for their restoration efforts involving three dam removals. Among their revitalization efforts, the community is planning fishing access, a riverwalk, and a park to help highlight the restored river that flows through their downtown (see Baraboo River, p. 21).

A restored river can offer many recreational opportunities

Dam removal has been found to improve sport fisheries and other river based recreational opportunities.[31,32,33] Along with providing direct recreational benefits for participants, these opportunities can also bring outside money into communities through

Bountiful Recreational Opportunities and Community Economic Development

Kickapoo River, Wisconsin

The removal of Ontario Dam from the Kickapoo River in southwestern Wisconsin improved recreational opportunities on the river and enhanced local fishing and canoeing industries.

The dam was inspected shortly after a drowning near the structure in the late 1980s and was declared a public safety hazard. It was removed in 1992 at a total cost of $47,000, compared to estimated repair costs of up to $200,000.

Ontario Dam on the Kickapoo River failed a safety inspection in the late 1980s. The dam was removed in 1992 (photo courtesy of Wis. DNR).

Canoeists paddle down the Kickapoo River. The number of canoe rental businesses has increased since the Ontario Dam removal (Trout Unlimited photo).

A young girl fishes in the Kickapoo River. Angler expenditures annually top $1 million in the rural Kickapoo Valley (Trout Unlimited photo).

In concert with improving land use in the watershed, the removal of Ontario Dam has provided many benefits, including reduced flooding, improved fishing, better canoe access, and related financial benefits to rural communities along the river.

Since the early 1990s, the number of canoe rental businesses has increased and existing businesses have increased the number of canoes for rent. During the summer of 1999, an estimated 16,000 people canoed on the Kickapoo River.

According to a university study, non-local canoeists spent $1.2 million on lodging, canoe rentals, groceries, gas, and other items in 1999. This revenue helps support 36 area jobs, through both direct services to recreationists and the ripple effect of more income in the local economy.[34]

The dam's removal has also resulted in cooler, less silty water. These conditions are much better for trout, and the Kickapoo is now a Class II trout stream supporting both brown trout and wild brook trout. Fishing is a popular activity in the watershed, and non-local angler expenditures are today more than $1 million annually.

tourism related activities like shopping and lodging (see sidebar, p. 20).

Removing a dam restores a stretch of river to its free flowing state, allowing it to more naturally support fish populations and habitat, which, in turn, can attract anglers. Removal may also result in increased use by canoeists and kayakers, who can freely and safely float with out encountering slack water or obstructions.

The value of water based recreation has been noted in numerous studies over the years, including many that attempt to attach eco nomic values to particular types of activity. Walsh and others[35] compiled the results of many of these studies to estimate economic values of different types of recreation (Table 7).

Walsh's analysis suggests an interesting poten tial economic benefit of dam removal and revi talized riverine fisheries. The still water in dam impoundments can cause water temperatures to warm. Warming of even a few degrees can inhibit the survival of coldwater species. If a river naturally supports a coldwater fishery, removing a dam and restoring the natural and potentially more economically valuable trout or salmon fishery could be an economic boon for a community, especially if there are no other nearby coldwater fisheries. High quality coldwater habitat is relatively rare, and that scarcity can increase the value to anglers of sites that are high quality.

Dams also block runs of migratory fish that need to swim up freshwater streams in order to reproduce. Removing a dam can help restore both coldwater and migratory fish populations where rivers would normally support such pop ulations. In other cases, by improving water quality and habitat connectivity, small dam removal can also help restore warmwater spe cies such as smallmouth bass (see sidebar, p. 30).

Sport fishing is a growing industry

Many state economies get billions of dollars of income from sport fishing. If sport fisheries are improved following a dam's removal, the potential economic benefits to communities can be significant (see sidebar, p. 23).

Ripple Effect: How Recreation and Tourism Money Helps the Economy

The "ripple effect" captures the magnifying impact of a dollar spent in a community. As an example, the American Sportfishing Association's *The 1996 Economic Impact of Sport Fishing in the United States*[36] describes the ripple effect as follows:

Each dollar spent by an angler increases another person's income, enabling that person (or business) to spend more, which in turn increases income for somebody else. The process continues as a wide series of ripples through local, regional, and national economies until the spreading fragments of the original dollar become so small they can no longer be measured.

If you fish in southern Wisconsin, for example, you might have stopped in at the Ace Hardware store in La Crosse. Here sales clerk Ron Gehrke is liable to suggest some RC Buzzbait lures for the local, largemouth-bass fishing. So you plunk down $10 for a trio of likely lures and head happily for the nearest bass pond. Then that $10 starts a ripple effect, spreading outward just like the ripples made when your lure hits the water.

Part of that money goes into Ron's wages helping to buy clothes for his kids at the local Farm & Fleet store. Part goes for income taxes, and yet another part goes into the store's overhead, paying for things like the electric bill from Northern States Power. And part of that money goes to Bettendorf, Iowa, where Ryan Coon of RC Tackle has a part-time business assembling lures in the family basement. Ryan pays bills, too, of course, and the rippling cycle further spreads and repeats. Included therein is money for basic family needs such as health care and telephone repair, which is how the effect of your tackle purchase spreads far beyond the doors of a sporting-goods store.

Ten dollars isn't very significant, of course, but when 35 million anglers spend $37.8 billion in 12 months the result in jobs, wages, and other economic effects is both extraordinary and at the very foundation of America's economic health.

Revitalizing Downtown by Reconnecting with a Free-Flowing River

Baraboo River, Wisconsin

The removals of Waterworks Dam in 1998 and Oak Street Dam in 2000 from the Baraboo River in downtown Baraboo, Wisconsin, have helped bring the community back in touch with its namesake river. According to a local newspaper, the river restoration "has spurred an economic revitalization effort in the downtown area and has suddenly made the river a hot spot for canoeists and kayakers."[37]

The Baraboo River flows over the Oak Street Dam, a stone's throw from downtown Baraboo, Wisconsin. The old dam's 2000 removal is helping the city reconnect with the river (photo courtesy of River Alliance of Wis.).

A new grassroots group, Citizens for Waterfront Revitalization (CWR), has been leading development plans to revamp Baraboo's downtown. Working with business and civic leaders, the CWR is planning a riverwalk along the river, a riverside park, a fishing dock, and a renovated bridge to give motorists a better view of the river. In addition, the community is commemorating the dams and their historical contributions to the region with dam history displays and a photographic history book.

According to a leader of the CWR, "Removal of the dams along the Baraboo Rapids has brought a heightened awareness of the historical significance that the dams had on the Baraboo area and its initial development. CWR is taking a lead role in promoting both economic and aesthetic revitalization along the Baraboo Riverfront."[38]

The community hopes their beautification plans will draw more people to Baraboo's downtown and waterfront, which is also home to Circus World Museum, the historic winter home of the Ringling Brothers Circus, a popular tourist attraction.

Canoeists enter the restored "Baraboo Rapids" which had been covered by Oak Street Dam for over a century. This artist's sketch depicts revitalization plans for downtown Baraboo (sketch courtesy of CWR).

Removing the dams has also improved the Baraboo River's water quality and sport fishery. Since the dams were removed, researchers have found 13 more species in some stretches of the river, including darters and smallmouth bass, fish that do not tolerate poor water quality.[39]

When the downstream Linen Mill Dam is removed in 2002, 120 miles of river will be flowing freely for the first time in more than 150 years.

Table 7. The Value of Recreation

Estimated median net economic values per recreation day by type of activity. The median is the middle value of an ascending series and expresses a central value much like an average.

Activity	*Median Value* (1999 dollars)*
Saltwater fishing	$78.24
Migratory fishing	$67.81
Coldwater fishing (e.g., trout)	$41.78
Boating, Motorized	$37.65
Boating, Nonmotorized	$37.19
Winter Sports	$35.77
Hiking	$34.64
Warmwater fishing (e.g., bass)	$33.00
Nonconsumptive fish and wildlife	$30.05
Sightseeing and off-road driving	$28.92
Camping	$27.75
Swimming	$27.28
Other recreation activities	$23.55
Picnicking	$18.80

* The standard unit of measurement is an activity day, defined as one person on-site for any part of a calendar day.

Adapted from Walsh, et al., 1992.[35]

According to a sport fishing survey, more than 35 million people fished during 1996 in the United States (Table 8). That is more than twice the number of people who attend NFL football games each year. Together anglers spend more than $37.8 billion on the sport. When other activities associated with fish ing are included, such as wages earned by people working in tackle shops, the economic activity sur rounding fishing rises to nearly $108 billion.[36] That is more than the gross state products of Montana, Idaho, Wyoming, North Dakota, and South Dakota combined.

Moreover, the sport fishing industry is growing in the U.S. While the total number of anglers has remained nearly steady from 1991 to 1996, total expenditures increased by $10.2 billion, or nearly 40 percent. This translates into an average value of more than $1,072 spent per angler per year, an increase in constant dollars of over $776 per angler from 1991.[36]

In addition, over the past several decades, the total number of anglers in the U.S. has increased signifi cantly from 17.6 million in 1955 to 35.2 million in 1996.[40]

Sport fisheries, such as smallmouth bass, northern pike, trout, and salmon, often recover dramatically after dam removal (see Tomorrow/Waupaca River, p. 25). If it is assumed that the number of anglers from outside a community will increase if a sport fishery is restored or improved, then communities can also expect increased economic activity.

Appendix I discusses the case of Woolen Mills Dam in West Bend, Wisconsin, where the number of people fishing in the Milwaukee River increased after dam removal. Many other dam removals have also resulted in improved sport fisheries.

Paddling is a growing industry

Canoeing and kayaking are rapidly growing indus tries in the United States. According to the Ameri can Canoeing Association, 24.8 million people went paddling in 1995.[41] In 1996, canoe and kayak sales totaled nearly $100 million and sales continue to grow.

Kayaking in particular is among the fastest growing outdoor activities, increasing by 50 percent in only four years from 1995 to 1999, with now more than four million participants.[42]

Our nation's tens of thousands of dams can make finding free flowing river stretches a challenge for paddlers. Furthermore, there are notably few remaining free flowing stretches of whitewater. The swiftest flowing portions of rivers and streams, which are a delight to many paddlers, have generally been the best places to generate hydropower and consequently have been the most viable spots for dams. In some regions, the only meaningful opportu nities for whitewater paddling today are when larger dams have scheduled water releases.

Water trails — stretches of river, lake, shoreline, or ocean that have been specifically established as trails for recreational boaters — are increasing in popular

Angling Dollars Can Help Local Communities

Three recent studies assessed the economic impacts of trout fishing in local communities based on angler expenditures. These studies demonstrate the economic ripple effect by showing how revenue from trout fishing extends into other industries and supports jobs in local communities.

An angler hooks a trout. Nearly 11 million people fly fish in the United States (photo courtesy of Rebecca Herrin).

Delaware River headwaters, New York. Revenue from trout anglers is a vital part of the economy in four small communities located in the headwaters of the Delaware River. In 1996, 31,000 anglers took advantage of the river's trout fishing, bringing almost $18 million into the four communities, which have a combined population of about 6,800. Nearly half (41%) of that money stayed within the local economy, supporting other businesses and individuals. The revenue from trout fishing supports 350 jobs in the four small communities.[43]

Kickapoo River/Timber Coulee Stream, Wisconsin. From 1994 to 1999, trout fishing in the rural Kickapoo Valley increased from a $300,000 to a $1.1 million industry per year. The number of anglers who visit the region each year has more than doubled since 1994 and by 1999 was up to nearly 9,000, most of whom traveled from outside the region. Visitors are spending more per trip, too. Approximately $76 per angler was spent per trip in 1994. By 1999, anglers spent $168 on each trip, mostly on eating, drinking, and lodging. Today, trout fishing supports more than 40 jobs in the rural area, which has a total population of 227,000.[34,44]

Beaverkill-Willowemoc Watershed, New York. Trout angling is one of the largest industries in Rockland, a small community of 4,000 within the Beaverkill-Willowemoc watershed. Area trout angling generated $2.3 million in wages in 1994, which supported 177 jobs. In total, trout anglers bring $4.8 million into the community, half of which is spent on food, beverages, and accommodations.[45]

An angler releases a rainbow trout. Retail sales of fly fishing equipment and apparel have been strong and increasing in recent years (photo courtesy of Russ Herrin).

Trout Fishing Nationally. Fly fishing is a popular sport in the U.S., with nearly 11 million participants.[46] In 1998, these anglers spent $572 million on fishing gear and apparel, a 9.2% increase from the 1997 total of $524 million. Retailers report that sales of rods, reels, waders, and apparel have each been growing. In 1997, 64% of all retailers experienced an increase in sales.[47] As noted in the cases above, millions of dollars are additionally spent during fishing trips on food, lodging, and transportation.

Table 8.
The Economics of Sport Fishing

The economic state of sport fishing in the United States based on a 1996 survey (1996 dollars).

Item	*1996*
Anglers	35.2 million
Days	625 million
Expenditures	$37.8 billion
Overall Economic Impact	$108 billion
Wages and Salaries	$28. 3 billion
Jobs	1.2 million
State Sales Tax	$1.9 billion
State Income Tax	$450.6 million
Federal Income Tax	$3.0 billion

Source: Maharaj et al., 1998.[36]

ity in the United States. The use of existing trails is increasing greatly, more trails are being developed, and more communities are beginning to use water trails to promote tourism. Dams can be an impedi ment to water trail recreation in many places because they make rivers less navigable, can pose a safety risk, and necessitate increased portaging (i.e., boats must be lifted out of the water and carried around them).

According to North American Water Trails, a coali tion of water trail organizations, dam removal can equate to greater economic opportunities for com munities that wish to establish a water trail.[48] The presence of a water trail brings more people to the river and increases business for local outfitters.

With so few free flowing river miles throughout the country, removing small dams can significantly improve opportunities for paddlers and potentially create new economic opportunities for communities as the paddlesport industry continues to grow (see Apple River, p. 26).

Dam removal is a cost-effective means for improving water quality

As relatively stagnant collection areas for nutrients and sediment, impoundments behind dams often have poor water quality. Excessive growth of algae and other vegetation common in impoundments can cause dissolved oxygen levels to drop, particularly during summer nights when plants are consuming the most oxygen. Decaying plant material in an impoundment can also contribute to declines in dis solved oxygen. Maintaining dissolved oxygen levels is crucial for aquatic life.

In addition, dams and their impoundments often cover stretches of natural river rapids because these steeper sites have high velocity flows to spin hydropower producing turbines (see Apple, Bara boo, and Willow River case studies). Uncovering rapids by removing dams can help improve water quality because free flowing rapids aerate water, maintain water temperature, and carry sediment downstream, clearing fish spawning gravels.

From an economic standpoint, poor water quality can inhibit recreational use of a water body and increase water treatment costs. Poor water quality can also reduce waterfront property values[49] (see land values section, p. 31).

Removing a dam can be one of the most cost effective and efficient methods of improving the water quality of a river or stream. Dam removal can restore the flushing flows of moving water and elimi nate the conditions that result in dissolved oxygen declines. Flowing water transports sediment and nutrients downstream rather than allowing them to accumulate in one place, and flowing water serves to dilute and distribute pollutants.

Section 303(d) of the Clean Water Act, established in 1972, requires that states maintain a list of 'impaired waters', those water bodies that do not meet that state's water quality standards. According to the law, states must develop Total Maximum Daily Loads (TMDLs) for the impaired waters and submit them along with the list to the Environmental Protection Agency (EPA) for approval. A TMDL is the maxi mum amount of pollutants that a particular water body can receive from all sources while remaining within water quality standards.[50]

Restoring a First-Class Trout Stream

Tomorrow/Waupaca River, Wisconsin

Nelsonville Dam on the Tomorrow/Waupaca River had the dual distinction of being Wisconsin's last commercially licensed water-driven gristmill and the first Wisconsin dam removed for the express purpose of improving a fishery.

Nelsonville Dam and its impoundment degraded fish habitat in the Tomorrow/Waupaca River in Wisconsin. The dam was removed for the express purpose of improving the fishery (photo courtesy of Wis. DNR).

Built in the 1860s, the dam blocked the river and significantly harmed native fish habitat. Agricultural runoff and sediment nutrients created undesirable algal blooms in the millpond, and the increased temperature of its impoundment caused a warmwater fishery to develop on this naturally high-quality coldwater trout stream.

The Wisconsin Department of Natural Resources (DNR) purchased Nelsonville Dam in 1984 for the purpose of removing it and restoring the spring-fed trout stream.

The removal of the dam, along with related bridge and roadwork, cost $62,000 and was partially funded by Wisconsin's Inland Trout Stamp Habitat Development Program. The former dam site was restored by planting vegetation, stabilizing the former impoundment bed with riprap, and stocking the river with trout.

An angler casts a fly on the Tomorrow/Waupaca River near Nelsonville. When Nelsonville Dam was removed, over a mile of highest quality trout stream was restored (photo courtesy of George Sroda).

The old mill building was deeded to the Portage County Historical Society. It now provides a facility for art shows, concerts, and other community events.

According to the Wisconsin DNR, water quality below Nelsonville has improved, and over a mile of highest-quality (Class I) trout stream has been restored in and above the old millpond site. Today some 38 miles of the Tomorrow have naturally reproducing brook and brown trout above the former dam site.

New River Businesses

Apple River, Wisconsin

The removal of Somerset Dam in northwestern Wisconsin allowed new businesses to grow, including a thriving tubing industry.

Somerset Dam stood for more than a century in Wisconsin's Apple River. The dam failed in the early 1960s and was removed in 1965 (photo courtesy of Wis. DNR).

Somerset Dam was built on the Apple River for hydropower during the 1850s. The dam washed out during a flood in the early 1960s.

Tubers approach the renewed rapids at the former Somerset Dam site. The dam's removal reconnected eight miles of the river, helping the tubing industry to thrive (photo courtesy of Apple River Hideaway).

Northern States Power (NSP) transferred ownership of the dam to the City of Somerset in 1963, and the remaining structure was completely removed in 1965. NSP and Somerset shared the $75,000 cost of removal.

Since the removal of the dam, tubing and camping businesses have prospered, including the establishment of several new businesses. The former dam site now marks the beginning of a series of rapids that are popular with river floaters.

Currently, five businesses offer tube rentals and access to an eight-mile stretch of free-flowing water between the Apple's two remaining dams.

One area resource manager notes, "The tubing industry wouldn't be what it is today without the dam removed."[51]

Scientists and resource managers are increasingly recognizing the role of dams in deteriorating water quality. Selectively removing dams is being explored in some places as a potentially cost effective option to achieve TMDL goals. In 2000, Ohio EPA recommended the removal or modification of two dams on the middle Cuyahoga River to eliminate drops in dissolved oxygen caused by algae growth and stagnant water in the dams' impoundments.[52] The middle Cuyahoga is on Ohio's 303(d) impaired waters list. Both the Munroe Falls and Kent Dam impoundments have had dissolved oxygen measurements that violate standards. The Ohio EPA recommendations state, "Elimination or modification of the dams would greatly improve habitat conditions and dissolved oxygen concentrations and would allow fish to migrate." Without removing or modifying the dams, two wastewater treatment plants on the river would have to undergo expensive improvements to reach TMDL goals.

On the Naugatuck River in Connecticut, eight dams are being removed or modified along with wastewater treatment plant upgrades in an effort to clean up a river that has been degraded by industrial pollution for decades. (see Naugatuck River, p. 28).

Removing small dams can help restore river systems

Because a single dam removal can potentially restore many river miles, small dam removal is increasingly being considered as a tool for restoring river systems on a watershed basis. A watershed is the land that drains to a certain water body. The river systems of many watersheds in the United States are fragmented by tens to hundreds of small dams with cumulative effects that impair water quality, damage fish habitat, and prevent natural river function. Federal and state environmental and natural resources agencies are increasingly making comprehensive assessments of entire watersheds and river systems, and implementing plans for watershed wide restoration efforts. With this broader water based focus, they are beginning to remove small dams and reduce the impacts of remaining dams (e.g., through improved operation or effective fish passage devices) to benefit entire river systems.

Two examples of these watershed wide efforts include the Connecticut Department of Environment Protection's projects in the Naugatuck River watershed and the work of the Pennsylvania Fish and Boat Commission in the Susquehanna River watershed. Both of these efforts are comprehensive plans to improve fish habitat and water quality and include the removal or modification of several dams throughout a river system.

When restoring a river system and its habitat, various restoration alternatives often need to be examined in order to determine cost effective approaches and the most efficient means for accomplishing objectives. Removing small dams can be the most cost effective and biologically effective means of restoring fish habitat and increasing fish populations (see sidebar, p. 30). Although costs can vary widely, according to the Wisconsin Department of Natural Resources, a small dam can be removed for about the cost of two miles of instream trout habitat work (including such work as installing habitat structures and associated bank stabilization), while potentially restoring many miles of habitat.[53]

On the Conestoga River in Pennsylvania, ten small dams have so far been removed, improving river habitat at a cost of less than $12,000 per mile (see Conestoga River, p. 29). For comparison, in stream restoration efforts for fish habitat — including such measures as bank stabilization and installation of fish habitat structures — can cost $30,000 to $50,000 per mile. Note that the cost effectiveness of restoration techniques cannot be directly compared because each application has site specific issues. This comparison is intended to give an idea of cost ranges.

Dam removal can be the most cost-effective *and* biologically effective means of restoring habitat.

A study on the Milwaukee River South watershed in Wisconsin found that small dam removal costs less per acre of habitat restored for smallmouth bass than implementing best management practices or purchasing streambank easements.[54]

A Watershed-Wide Water Quality Improvement Plan

Naugatuck River, Connecticut

During the industrial boom of the 19th century, factories and municipalities openly dumped waste into Connecticut's Naugatuck River.

By the late 20th century, the Naugatuck was considered one of the most polluted rivers in Connecticut. Numerous dams along the river inhibited its natural flow patterns, which otherwise would have helped dilute the pollutants.

The Connecticut Department of Environmental Protection (DEP), local Trout Unlimited volunteers, and other partners recently began an unprecendented watershed-wide effort to restore the Naugatuck River. The plan involves removing or modifying eight dams and upgrading several wastewater treatment plants that discharge into the river.

Union City Dam on the Naugatuck River was one of eight dams modified or removed. The unprecented watershed wide clean up is improving the river's habitat and water quality (photo courtesy of Milone & MacBroom).

As a result of the Naugatuck Restoration Project, four dams have been removed as of 2000, at the following costs:

- Union City — $139,300
- Freight Street — $75,700
- Anaconda — $56,000
- Platts Mill — $111,400

Four additional dams are either pending removal or are being modified to provide fish passage.

A stretch of the Naugatuck River flows freely following the removal of Union City Dam. The swift flowing upstream riffles help improve water quality by speeding diluting flows and aerating the water (photo courtesy of Milone & MacBroom).

Along with treatment plant upgrades that have been completed, dam modifications and removals have been a cost-effective means of dramatically improving the Naugatuck's water quality.

At its completion, the pro-active project will have improved habitat and water quality in 32 miles of the Naugatuck River, restoring passage for sea-run brown trout, American shad, alewives, blueback herring, and other aquatic species.

A Cost-Effective Tool for Fisheries and Watershed Restoration

Conestoga River, Pennsylvania

Ten dams were removed from the Conestoga River and its tributaries in Pennsylvania between 1996 and 2000 as part of a watershed-wide effort to restore the river's once vibrant fisheries.

With seven more dams pending removal, the goal is to restore the river's historical American shad runs. Many years ago, shad would migrate from the Atlantic Ocean through Chesapeake Bay and the Susquehanna River to reach spawning grounds in the Conestoga. However, since 73 blockages were built on the river and its tributaries, the migratory shad have been unable to reach these historic spawning grounds.

The dam removals are proving to be a cost-effective tool for restoring aquatic habitat in the Conestoga. The first nine dams were removed at a total cost of under \$300,000. Their removal has opened up more than 25 miles of river to migratory shad and other species, at a cost of less than \$12,000 per mile.

Boaters paddle down a restored free flowing stretch of the Conestoga River. Ten dam removals on the river have helped both recreation and fish habitat (photo courtesy of Lancaster County Canoe Club).

The Conestoga River rushes through a breach in the Rock Hill Dam, one of ten dams removed from the watershed from 1996 to 2000. Seven more dams are scheduled for removal as part of a watershed wide effort (photo courtesy of Penn. Fish & Boat Comm.).

The Pennsylvania Fish & Boat Commission estimates the improved habitat will result in 50,000 angler trips to the river each year to the restored American shad runs. Pennsylvania expects this to generate another \$2 to 3 million per year for local economies.[55]

In the spring of 2000, American shad that were stocked as young, recently hatched fish four years earlier, were found as adults in stretches of the river. After being absent from the river for 88 years, these fish were able to imprint on the Conestoga. In other words, they instinctively returned to its free-flowing reaches after their migratory journey to the Atlantic Ocean.[56]

Dam Removal Is Biologically Effective for Restoring Habitat

Fisheries biologists were among the first to recognize that removing dams can be an effective way to restore fish habitat. One study by fisheries biologists on the Milwaukee River South watershed modeled the fish habitat that would be created by different management techniques. Their modeling showed that removing dams would restore more habitat for two highly valued sport fish, smallmouth bass and northern pike, than other fishery management techniques, such as buffer strips and sediment control techniques (Figure 1).

The benefit of dam removal to fisheries is increasingly confirmed by real-world cases. A fish survey on the Baraboo River following the removal of Waterworks Dam found 24 species of fish, more than double the 11 species found during a survey two years earlier with the dam in place. Species diversity is an indicator of river health. The survey also found 87 smallmouth bass in a stretch where only three were found before the dam's removal.[39]

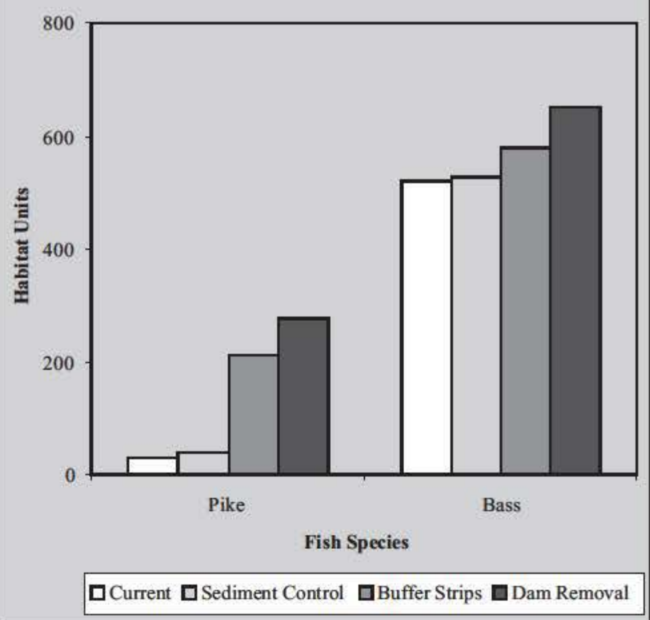
Just one year after the removal of Edwards Dam from the Kennebec River in Maine, alewives and other species returned in numbers that had not been seen for more than 160 years since the dam was built. After the removal of Woolen Mills Dam from the Milwaukee River, smallmouth bass populations increased substantially from nearly zero in portions of the river.[31]

After the removal of ten dams from the Conestoga River in Pennsylvania, American shad migrated back from the Atlantic Ocean for the first time in 88 years.[56]

The number of examples like these continues to grow, attesting to the success of restoring fish and other habitat by removing dams.

Figure 1.
Dam Removal Improves Habitat

Total potential habitat for representative fish species under various habitat management options for the Milwaukee South watershed. Fisheries biologists recognize dam removal as one of the most effective means for habitat restoration.



A habitat unit is equal to one acre of "optimum" habitat for a species.

Source: Pajak, 1992.[54]

Land Values and Small Dam Removal

One of the most controversial issues in discussions about dam removal versus repair concerns the effect removal might have on neighboring property values. A common assumption is that when the impoundment is gone, nearby property values will drop. To date, there have been few studies that address this topic, but anecdotal evidence and some preliminary research indicate that property values do not necessarily decline after a dam is removed.

Because little hard data is available and the potential economic impact on land around former impoundments is a common sticking point in dam removal discussions, Trout Unlimited conducted preliminary research on the topic (see Appendix I: The Case of Woolen Mills Dam and the Milwaukee River). The study looked at a case in a small community where a small dam had been removed 10 years earlier, and the river and former impoundment restored in a thoughtful manner. According to property owners and a local realtor, the predicted decrease in property values around the former impoundment did not occur.

Property values can decline with a dam in place.

In fact, property values can decline with a dam in place. Because of sedimentation, eutrophication, and the general lack of oxygenated flushing river flows, dam impoundments often have poor water quality. Several studies have shown that poor water quality adversely affects nearby property values. For example, one study in Massachusetts showed that residents around the Neponset Reservoir suffered financial loss due to changes in water quality that reduced the reservoir to an unsightly and obnoxious nuisance in the summer. The study estimated that the 160 lots around the reservoir were worth $13.7 million less than they would have if the reservoir water were clean — a 40 percent loss in value.[57]

Another study, of homes adjacent to St. Albans Bay in Vermont, estimated a 20 percent decline in property values due to poor water quality.[58] A study of a large number of lakes in Maine concluded that changes in water clarity caused a decline in shoreline property values. Every meter of water depth visibility lost due to poor water quality caused property values to drop by five percent.[59]

Studies have also shown that properties near open space can have higher sales prices, better marketability, and faster sales than properties away from open space.[60,61,62,63,64,65,66] Both the lake environment of a dam impoundment and the riverine environment following a dam removal can be considered open space and accordingly, either could add value to a property. Similarly, when a dam is removed, the land formerly covered by the impoundment is often some type of open space and could enhance property values, whether it is restored wetlands[67] or other natural environment, or converted to parkland (see Willow River, p. 32). One study in Michigan found that property frontage along the AuSable River "was at least equal to, if not more valuable than, 'lake' or reservoir frontage."[68]

Proximity to natural areas in general is typically a desirable trait for real estate. Following a preference in the late 1980s for proximity to so called "built" environments (e.g., tennis courts, fountains), trends, begun in the 1990s, appear to be heading toward preferences for more natural environments. In addition, the relative scarcity of these environments can increase their value. As more and more dams are removed, homebuyers may make the distinction between the built environment of a dam, versus the natural environment of a free flowing river.

The effect of dam removal on property values around an impoundment is a subject that needs more study, but enough research and anecdotal evidence exists to indicate that one should not assume property values will decline. In many cases, when dam removal includes thoughtful restoration — of the river and adjacent lands — property values need not decline. Indeed, when the dam removals of today are evaluated 10 years hence, some property values may even increase, especially where poor water quality in the impoundment was a factor.

Restoring Natural Beauty

Willow River, Wisconsin

Willow Falls Dam and Mounds Dam were both built on the Willow River in northwestern Wisconsin in the late 1800s to power lumber and flour mills. The dams were later used to produce electricity.

By 1963, neither of the dams was in use, and both were donated to the state — along with 1,300 acres of land — for what would become Willow River State Park.

Willow Falls Dam stood 60 feet over the Willow River downstream. Time and flowing water rotted the concrete structure and it was removed in 1992 (photo courtesy of Wis. DNR).

By the 1990s, the dams were in very poor condition. Willow Falls Dam was found to be beyond repair, and repair costs for Mounds Dam were estimated at $3.3 to 6 million. Estimates for removing the dams were $622,000 for Willow Falls and $1.1 million for Mounds Dam. Willow Falls Dam was removed in 1992. Following lengthy and controversial debate, removal was determined to be the best option for Mounds Dam as well because of the cost differences between repair and removal. The structure was removed in 1998.

Both dams cost much less than originally estimated to actually remove — $450,000 for Willow Falls and $500,000 for Mounds.

Removing the dams has been positive for both the fisheries and Willow River State Park. Four miles of the Willow River was restored and now sustains a trout fishery. (However, a dam subsequently repaired upstream is keeping water temperatures too warm for the trout population to reproduce naturally.)

Willow Falls is a centerpiece of Willow River State Park. The natural flows of the scenic waterfalls were restored by the removal of Willow Falls Dam (photo courtesy of David Gilbraith).

Willow Falls Dam removal also restored natural flows to scenic Willow Falls. The Falls are now a popular attraction at Willow River State Park, which is just outside of Minnesota's Twin Cities and draws more than 300,000 visitors a year.

Conclusion

As the hundreds of thousands of small dams that helped power our nation's growth continue to age, more and more communities are faced with decisions to repair or remove these structures. These decisions are often contentious, marked by confusion and misinformation, and narrowly focused on a small number of the many issues. While having more complete and accurate information may not relieve all of the tension, it can help communities make more informed decisions.

Many communities that have chosen to remove a small dam continue to realize a number of economic benefits. The most obvious benefit, and the one that drives many decisions to remove small dams, is that repairing a dam is usually more expensive than removal. In the cases studied in this report, the cost of repairing a dam averaged more than three times the cost of dam removal. In some cases the cost difference can be even greater.

Removing a dam can relieve the financial burden of maintaining and repairing the dam structure as well as the safety liability associated with the structure. It can also relieve recurring costs associated with maintaining water quality and fishery management.

Many of the benefits of dam removal, as well as many of the costs and benefits of repairing and maintaining a dam, occur over the long term. A thorough decision making process needs to include more than a simple comparison of the short term cost of repairing a structure versus the demolition cost of removal. It needs to consider all of the costs and benefits of each option, both immediate and well into the future.

Experience has shown that communities that embrace the opportunity to reconnect with a naturally functioning, free flowing river through a thoughtful restoration plan are the most likely to see the greatest economic benefits from a small dam removal. Such plans include the concerns of the resource agencies, the community, and other stakeholders, including water users.

As the local community is brought in touch with the river through such amenities as riverwalks, parks, and increased access for boating and fishing, the improved recreational opportunities build an additional potential for tourism and associated commercial benefits. In several communities, small dam removals have been catalysts for downtown revitalizations, local fishing and boating industry development, and watershed wide recreation plans. As more people come to experience the river, associated economic benefits come to the communities that provide access to the river.

While not all of the benefits of removing a small dam will occur in every case, an understanding of the potential benefits can help communities imagine the possibilities. When managed thoughtfully, a community's loss of a small dam can bring about meaningful gains in recreational and commercial opportunities, and in the health of the river.

Appendix I: The Experience of West Bend, Wisconsin, and the Milwaukee River Restoration

In 1988, Woolen Mills Dam was removed from the Milwaukee River in West Bend, Wisconsin. While every dam removal has unique aspects because of dif ferent socioeconomic, biological, and engineering issues, this project is highlighted here primarily for two reasons. First, although the decision making process was contentious at times, overall the dam's removal and the restoration of the river and sur rounding land was managed particularly well by the community and resource managers. Second, the pro ject has more complete pre and post monitoring data than most projects, including economic, water quality, and fisheries information. Woolen Mills Dam was removed more than a decade ago, allowing time for reflection on the project and its impacts on the river and the community.

The Woolen Mills Dam removal is characteristic of the issues many communities are facing with respect to the dam's size and condition, small town sur roundings, safety issues, current and former dam uses, fisheries issues, water quality issues, sediment issues, project costs, and concern about property values.

In other ways, the dam's removal is not typical; a great deal of land was regained for public use from the impoundment and, at the time, it was uncom mon to have such a comprehensive restoration plan developed by the community and resource manag ers. Inevitably, the most successful restoration pro jects are guided by thoughtful plans, both to physically restore the environment and to provide benefits for the surrounding community.

The Story

Woolen Mills Dam was originally a wooden structure built in 1870 by the city of West Bend to power a sawmill, and later a woolen mill. In 1919, Wisconsin Power and Electric (WPE) rebuilt the dam as a concrete hydropower structure. The reser voir created by the 18 foot high dam was locally known as West Bend Pond. When built, the pond had a surface area of 67 acres and a mean depth of about 15 feet.

In 1959, when it was no longer economical to main tain the dam as a hydropower facility, WPE legally abandoned it and transferred ownership to the city of West Bend.

By 1980, the dam was badly deteriorating and had become a public safety hazard. It was no longer gen erating hydropower, and its impoundment was spar ingly used for recreation, including some fishing, swimming, and ice skating. Following a safety inspection, the Wisconsin Depart ment of Natural Resources ordered that the dam be repaired, rebuilt, or removed. After long contemplation and public discussion, it was agreed that the dam should be removed, primarily because of the high cost of the necessary rebuild.

Woolen Mills Dam stood in the Milwaukee River in West Bend, Wisconsin, for 118 years. The deteriorating structure was removed in 1988, avoiding a $3.3 million cost to rebuild it (photo courtesy of Wis. DNR).

Ultimately, the community gained a more healthy and naturally func tioning river, including associated wetlands. Water quality improved and recreational opportunities increased. Sixty one acres of land were reclaimed from the former impoundment and were used to expand the existing Riverside Park. The park today includes heavily used hiking and biking trails, foot bridges, fishing access, a canoe launch, and athletic fields. A walking path winds around a restored native prairie and crosses over several scenic walking bridges that span the river.

The following describes many of the costs and benefits of the decision.

Who Paid?

The city of West Bend paid for the $86,000 cost of the structure's removal. Through the Wisconsin Stewardship Program, the state Department of Natural Resources assisted the city with restoration efforts by paying 50% of the costs for park development, including a canoe launch, athletic fields, trails, pedestrian bridges over the river, fishing access, and parking. The city and the state also shared project costs of design and engineering, seeding, and riverbank stabilization work.

Cost Comparison

The decision to remove Woolen Mills Dam hinged on the substantial difference between the direct costs of rebuilding and removing the dam. On one hand, the cost estimate to rebuild the dam was $3.3 million, including associated costs of extending a road and bridge over the dam. West Bend, a moderate sized community of around 24,000 people, could not afford a cost of this magnitude. On the other hand, it cost $86,000 to remove the structure.

However, a comparison of these direct costs does not tell the entire financial story. Both rebuilding and removing the dam had additional costs that either were incurred or potentially would have been incurred (Table 9 and Table 10). For example, Woolen Mills Dam had operation and maintenance costs of approximately $10,000 per year. A rebuilt dam may or may not have cost the same to operate, but certainly would have had annual costs which, along with potential costs for future repairs, would have added up over the life of the dam.

In addition, there were liabilities associated with the dam because it had no capacity to store floodwaters. Following one large storm, the city paid over

Table 9. Estimated Costs of Rebuilding Woolen Mills Dam

Estimated costs for rebuilding Woolen Millls Dam, along with associated bridge construction and West Bend Pond water quality management.

Activity	***Cost ($)***
Rebuilding dam, bridge, and road extension	3,300,000
ADDITIONAL COSTS	
Dredging West Bend Pond	972,000
Additional pond water quality management (macrophyte harvesting, nutrient inactivation, sediment covering)	11,900 per year
Improved watershed management practices (erosion control and urban land management)	24,800 per year
Operation and maintenance of the dam	not estimated*
Future dredging of West Bend Pond	not estimated*

* included to show costs that should be considered but were not estimated

Source: West Bend Parks Dept. Files, 1979, SEWRPC

Table 10.
Costs of Woolen Mills Dam Removal, River Restoration, and Recreational Park Development

Activity	*Cost ($)*
Dam Removal	82,000
Initial seeding	33,000
Engineering and contract hydrologic studies, design work	73,000
Final grading and seeding	861,000
Bridge construction and river rerouting	800,000
Park Development	549,000
Fish Restoration	32,000
TOTAL INITIAL COSTS	**2,430,000**
ADDITIONAL COSTS	
Park operations and maintenance	~ 8,000 per year
Potential future repairs and upgrades to park facilities	not estimated*

* included to show costs that should be considered but were not estimated

Source: West Bend City Engineering Dept. and West Bend Parks Dept.

$100,000 for property damages caused by upstream flooding exacerbated by the dam. If a new dam were rebuilt, a more effective spillway could have reduced some of the risk of flood damage, but the impoundment still would not have had the capacity to store floodwaters. By removing the dam, this liability was removed.

In 1979, the Southeast Wisconsin Regional Planning Commission (SEWRPC) recommended a variety of management procedures to improve the degraded impoundment's long term water quality (Table 9). The overall objective was to reduce the pond's nutrient levels and restore its depth to an average of 15 feet from its six foot depth at the time of the study. Dredging the impoundment to this depth would have cost $972,000 in 1980 dollars.

Dredging would have restored the depth of the pond, but the pond would have started to fill in again as the river deposited sediment and nutrients from the largely agricultural areas upstream of the dam. To reduce this buildup of material and delay the time between dredgings, improved management practices for the entire watershed would be needed. These practices, included in the SEWRPC recommendations, would have reduced amounts of sediment and nutrients in the water and generally improved water quality. Improved watershed management would have cost approximately $24,800 per year. Even with the dam removed, these management practices may have still been advisable, but the dam's removal ended the accumulation of materials in West Bend Pond.

River restoration and park development were the most substantial costs associated with the project (Table 10). In addition, the new bridge that was originally proposed as part of the dam repair was still built in conjunction with the dam removal, at a cost of $800,000. In all, the costs of removing the structure, building a bridge, restoring the stretch of river, and developing the park added to $2,430,000, still almost $1 million less than the cost of rebuilding the dam.

Park facilities also have operation and maintenance costs, and these costs are approximately $8,000 per year at Riverside Park. Over the long term, the park will likely need upgrades, which could amount to significant investments. The original cost of $549,000 for developing the park gives a general sense of what future upgrades could cost.

In the end, the choice for West Bend came down to rebuilding the dam, and thus preserving its moderately used impoundment, or removing the dam and

Four walking bridges span the Milwaukee River in West Bend. The bridges connect trails over parkland that was covered by water for more than a century. The trail system also connects to the downtown area (photo courtesy of West Bend Parks Dept.).

developing a well used park at a cheaper price. The removal of the dam brought additional economic benefits for recreation, community development, and for local businesses.

Recreational Benefits

Restoring a free flowing stretch of the Milwaukee River and developing Riverside Park has created a number of recreational opportunities for the sur rounding community.

According to local officials, prior to the removal of Woolen Mills Dam, few residents used the impound ment and surrounding area, with the exception of adjacent landowners. Following the removal, how ever, the city's Parks Department estimated that, combining all activities, there were more than 37,000 users in the newly developed section of the park in one year alone (Table 11).

Although there may be some overlap between people participating in different activities in the park, the overall number of users is greater than the entire population of West Bend. Possible dollar values of many of these new recreational opportuni ties were presented earlier (Table 7), and give a general sense of the increased overall value of the area to the commu nity.

Before Woolen Mills Dam was removed, researchers from the University of Wisconsin Stevens Point surveyed the recreational uses of West Bend Pond over a 25 day period in the summer of 1986.[69]

The survey observed eight people swimming in the impoundment and one person fishing during that entire period. It was concluded that recreational activities were sti fled due to poor public access for boats, the absence of a sport fish ery, and a silty pond bottom.

The researchers also noted that people fished and swam almost twice as much in the free flowing sections of the Milwaukee River just outside of West Bend.

Following the dam's removal, fishing in the former impoundment increased. During the summer of 1990, just two years after the dam was removed, a study found 51 anglers within the new, free flowing section of the river. These anglers contributed over 2,000 angler hours of fishing.[71]

While improved public access has contributed signif icantly to increased swimming and fishing in the restored river, improved water quality has also played a crucial role. Simply based on observation, a sediment filled pond was turned into a free flowing river with higher water quality that is fundamentally more attractive to anglers and swimmers.

A study five years after the dam's removal found that carp, a species tolerant of poor water quality condi tions that had been abundant in the impoundment, had essentially been replaced by smallmouth bass, a species that does not tolerate poor water quality.[32] In addition, during that time, the overall index of biotic integrity, a measure of stream health, improved from 'poor' in the reaches above the dam to 'good.'

Table 11. Former Impoundment Became a Recreational Area

Estimated number of users by activity in the expanded Riverside Park following the removal of Woolen Mills Dam. The figures are based on observation and some tracking by the West Bend Parks Department. Numbers are conservative estimates.

Activity	*Estimated Number of Users in 1999*
Trail Access: Canoeing, Fishing, Biking, Walking, Jogging, Rollerblading, Skateboarding, Picnicking, Sculpture Showcase Viewing, Wildlife Appreciation, Skiing, etc.	27,000
Adult Flag Football League on Football Field	800
Youth Football Instruction on Football Field	30
YMCA Youth Soccer League on Soccer Field	800
July 4th Fireworks Display from Parking Lot	5,000
Kettle Moraine Jazz Festival on Football Field	4,000
TOTAL	**37,630**

Source: Pruit, 1999.[70]

Community Benefits

Riverside Park, connected to downtown West Bend with walking trails, has become a center for community activity. There is a sense that the revitalized river and parkland have brought a feeling of pride to the community. In a 1999 West Bend quality of life survey, residents gave the riverwalk, which winds through Riverside Park, one of the highest approval ratings of any feature of the city.[29]

A member of the city's Rotary Club describes community sentiment about the changes, "People at first were very, very skeptical of what was going to happen. But of course now people know very well what's happened and the whole city is enjoying it...the whole attitude has changed and now people want to be down not only sitting along the river, walking along the river, but they also want to even be experiencing and touching the river. And so it really is a nice benefit for the public to have."[72]

Kids fish in the Milwaukee River in Riverside Park. Fishing has become popular in the river since the Woolen Mills Dam removal led to improved water quality and fish habitat (photo courtesy of West Bend Parks Dept.).

One new community benefit resulting from the dam removal is the annual Kettle Moraine Jazz Festival held in Riverside Park. The festival is hosted by the West Bend Sunrise Rotary Foundation, which raises money for local charities. The Rotary chose to hold the Jazz Festival in Riverside Park because of its unique ambience, natural beauty and restored character. The dam's removal and park development created a new venue that made the festival possible in that area[73] and is now a continuing source of community pride and charita ble income.

Benefits to Local Businesses

Restoration of the river and surrounding land is bringing important benefits to local businesses by bringing more people downtown and generally improving the quality of life in the community.

While there have been no studies yet quantifying changes in business activity within downtown West Bend following the removal of Woolen Mills Dam, having thousands more people coming downtown to use the adjacent Riverside Park and the Milwaukee River brings more visibility, and consequently money, to downtown businesses.

However, attracting more people downtown is not the only benefit to area businesses. Riverside Park and the free flowing Milwaukee River have become amenities that help businesses attract employees.

As the CEO of one local business described, "It is absolutely amazing to me that we could be so blind to this wonderful asset for so many years. You know, you don't realize what a wonderful thing having a river flowing through your town is. What does that mean when you're in business? Well, I have to recruit people to come to this town to go to work for this company. I can walk them down to our river and I can show them this beautiful river and kids fishing and public sculptures along the river, and I can take them to our cultural dis trict, which is not too far from the river, and show them those things. It's a big selling point in recruiting people to come to work for this company and in keeping them."[30]

Property Values

During the planning process to rebuild or remove Woolen Mills Dam, one issue in the forefront of many people's minds was how the removal would affect property values. Many residents were concerned that draining West Bend Pond would decrease nearby property values.

Bill Yoder of Appraisals, Inc., an appraiser in West Bend and surrounding Washington County for more than 20 years, including when Woolen Mills Dam was removed, shared this concern anticipating that adjacent property values would suffer.

However, eleven years later, having observed the changes that actually occurred, Yoder concluded that the removal of Woolen Mills Dam has had no effect on adjacent property values.

Phone interviews with four nearby residents support the appraiser's conclusion that property values were not affected. Property owners selected for the inter view were those still in the community who had owned property adjacent to the former impound ment both before and after the dam removal. Four residents met those criteria. Although this is a small sample, it nonetheless consists of a majority of the adjacent landowners who have been present before and after the dam was removed.

Three of these four residents were against the removal of the dam at the time, and still oppose the decision. Nonetheless, only one now believes that

The Milwaukee River flows through restored prairie in Riverside Park. Many local residents were concerned that this area would become unsightly mudflats after the Woolen Mills Dam removal (photo courtesy of West Bend Parks Dept).

the property decreased in value. The remaining three homeowners believe that the dam's removal had no effect.

Sales records in West Bend suggest a similar conclu sion. Records show that five parcels adjacent to the former impoundment have been sold since 1996 (Table 12). These sales were compared to similar property sales within West Bend that were not adja cent to the former impoundment.

In Table 12, "adjacent" properties refer to homes that were once next to the former impoundment, but are now next to Riverside Park. "Nonadjacent" parcels refer to other properties in West Bend that are less than a half mile from a park other than Riverside.

Because many variables are included in establishing the value of a home, attempts were made to mini mize variation by comparing single family homes with similar characteristics, such as date sold, lot size, square footage, total number of rooms, and the age of each home.

Table 12 shows five side by side comparisons of adja cent and nonadjacent homes with similar characteris tics. For the most part, the results show very similar sales prices for each of the comparisons.

Table 12. Property Values Remain High on Former Impoundment

Comparison of property values from land adjacent to the former West Bend Pond with similar property sold in a different location within the city of West Bend. Property values adjacent to the former impoundment have remained comparable with land near other parks in the city.

	Location	Date Sold	Sale Price ($)	Lot Size (ft.)	Square Footage	Sale Price per Square Foot ($)	Total Rooms	Age
1	Adjacent	6/96	134,900	85x154	1680	80.30	7	1967
	Nonadjacent	5/96	135,000	85x144	1622	83.23	7	1967
2	Adjacent	11/96	126,900	82x159	1522	83.38	7	1968
	Nonadjacent	9/96	125,000	89x130	1562	80.03	7	1958
3	Adjacent	7/98	136,000	82x159	1522	89.36	7	1968
	Nonadjacent	1/98	138,500	94x120	1793	77.24	7	1971
	Nonadjacent	8/98	122,900	110x126	1492	82.37	8	1963
4	Adjacent	1/98	156,000	112x106	1932	80.75	7	1968
	Nonadjacent	5/97	151,900	75x143	1826	83.19	7	1966
5	Adjacent	1/99	126,500	180x114	1616	78.28	6	1960
	Nonadjacent	6/99	105,000	140x120	1677	62.61	6	1950

"Adjacent" = properties that were next to the impoundment, and are now next to Riverside Park.

"Nonadjacent" = other properties in West Bend that are less than a half mile from a park other than Riverside.

The largest difference appears in comparison 5, where the selling price of the adjacent property was 20 percent more than the nonadjacent value. These properties are located on the same street, with the nonadjacent parcel next to the Milwaukee River, downstream from where Woolen Mills Dam formerly stood. The adjacent property is upstream from the former dam and formerly had a view of and access to West Bend Pond.

These results show that property values adjacent to the former impoundment hold similar value to properties adjacent to other parks in the area. In combination with the analysis of the local appraiser and interviews with property owners themselves, it is evident that property values have not declined dramatically more than a decade following the dam's removal. This conclusion is based on a preliminary study and on anecdotal information confirmed by local expert opinion. The scientific community could supply crucial information for decision makers by conducting additional research on this topic at different sites around the country.

Appendix II: Selected "Willingness To Pay" Studies

Studies from across the country increasingly show citizen support to restore rivers and remove dams. So called "willingness to pay" studies are one way economists attempt to capture nonmarket values of such things as clean water, scenic beauty, or environ mental preservation for future generations. The fol lowing discusses four such willingness to pay studies.

Elwha River: Elwha and Glines Canyon Dams

A study was conducted in 1996 to estimate the pub lic's willingness to pay for restoring the Elwha River ecosystem and its migratory fishery by removing two dams on the Olympic Peninsula in Washington State.[74] The two dams, Elwha and Glines Canyon, are both large dams with heights of 108 feet and 210 feet respectively.

Removal of the dams would restore 70 miles of free flowing river for declining fish populations. The willingness to pay estimates were based on expected increases in four species of salmon and steelhead asso ciated with removing the dams. The study area included:

- a sample of residents in Clallam County, where the dams are located,
- all other residents in the state of Washington, and
- households throughout the rest of the United States.

The researchers surveyed people using a method known as contingent valuation. Simply put, respon dents to a contingent valuation study estimate a value that they would be willing to pay for an activ ity to occur or not occur.

The estimated annual value per household for removing the two dams (Table 13) shows that resi dents in Clallam County were willing to pay $59 per household annually, while residents in the rest of Washington were willing to pay $73 per household annually. Residents from the rest of the United States were willing to pay $68 per household annu ally.

These values translate into a total benefit to Wash ington residents of $138 million annually for 10 years as a result of removing Elwha and Glines Canyon Dams. The estimate of total nonmarket ben efits to all U.S. residents, including Washington, ranges from $3 to $6 billion.

The researchers conclude that the results show a sub stantial nonmarket willingness to pay to remove dams to restore salmon and steelhead runs in the Pacific Northwest.

Clyde River: Newport No. 11 Diversion Dam

The University of Vermont and the National Wild life Federation conducted a willingness to pay study on the removal of Newport No. 11 Diversion Dam on the Clyde River in northern Vermont.[75] The rela tively small dam, 17 feet high and 90 feet long, blocked spawning and feeding grounds of declining landlocked Atlantic salmon populations.

The Department of Public Service (DPS) estimated that generating power from the dam would result in a total net benefit of $42,000 for Citizens Utilities' ratepayers over a 40 year licensing period. The DPS also estimated that operating the dam would save a projected $44,820 from "avoided air emissions" of other energy production. Together, these yield a benefit of $88,850 to continue dam operations.

The willingness to pay report assessed the value of removal within Orleans County, where the dam is located, as well as the rest of Vermont.

Similar to the Elwha study, the Clyde study used contingent valuation to estimate the demand (will ingness to pay) for removing the Newport Dam to help restore the Clyde River and landlocked Atlantic

Table 13. Citizens Value Elwha River Restoration

Willingness to pay for Elwha and Glines Canyon Dam removals. Units are average annual dollar values per household.

Clallam County	Rest of Washington	Rest of United States
$59	$73	$68

Source: Loomis 1996.[74]

salmon populations. In addition, the study assessed the willingness to pay for different types of recreation.

The results of the find ings are shown in Table 14. The study shows support throughout Vermont to remove the Newport No. 11 Diver sion Dam and its power generator. The com bined willingness of Orleans County house holds to pay $389,000 per year greatly exceeded the benefits of repowering the No. 11 generator.

Table 14. Citizens Value Clyde River Restoration

Willingness to pay to remove Newport No. 11 Diversion Dam by subset of sample. Units are average annual dollar value per household.

Subset of Sample	*Orleans County ($)*	*Rest of Vermont ($)*
All Households in Sample	65.43	50.98
River Recreationists	67.35	57.39
Non River Recreationists	62.55	41.99
Clyde River Recreationists	70.03	*
Non Clyde River Recreationists	60.97	49.66
Clyde River Anglers	72.14	*
Non Clyde River Anglers	64.56	*

* WTP values could not be calculated due to small sample sizes.

Source: Gilbert, et al., 1996.[75]

It is interesting to compare the Clyde River and Elwha River studies. While both studies show sup port for removing dams, note that in Table 13, Clallam County (site of the dams) was less willing to pay for the Elwha dam removals than the rest of Washington state. In contrast, Orleans County (site of the dam) was more willing to pay for the Clyde River dam removal than the rest of Vermont (Table 14).

This contrast gives some evidence of the different socioeconomic environments for dam removal in different communities and in different regions of the country.

Kennebec River: Edwards Dam

Freeman and others[76] reviewed a study by Boyle and others[77] that estimated anglers' willingness to pay to remove Edwards Dam from the Kennebec River in Maine. For more than 160 years, the 24 foot high Edwards Dam blocked flows on the Kennebec with out adequate fish passage.

The Boyle study used contingent valuation to esti mate the dollar value derived from improved fishing opportunities expected from the removal of Edwards Dam. The estimates were based on a sample of Maine residents and non residents holding inland fishing licenses. The results of this study are illus trated in Table 15.

Note that the values are significantly lower than in the previous two studies. Freeman and others[76] argue that these results underestimate the total economic value of the fishery because they derive from a spe cific sample size of anglers holding Inland Fishing Licenses.

They also include only *use values*, the benefit received by people who actually use the resource. They do not include *non use values*, the benefit gained by people who do not use the resource, but who find value knowing it exists. Therefore, one could not use these values to accurately estimate the

Table 15. Citizens Value Kennebec River Restoration

Willingness to pay for removing Edwards Dam, Kennebec River, Maine. Units are annual dollar value per angler holding an inland fishing license.

Type of Angler	*Willingness to Pay ($)*
Anglers living adjacent to the river	18.11
Other resident anglers	13.71
Nonresident anglers	11.85

Source: Freeman, et al, 1995.[76]

true benefit society receives from a restored fishery through dam removal. Loomis[74] and Gilbert and others[75] studied a sample of the entire population in the previous study discussed, which would include all users and non users of the fishery.

Freeman states that there is a net benefit to removing the dam despite the undervalued estimates of the fishery. He first assumes that the resource values that would be lost due to the drawdown of the impound ment would be negligible. Therefore, the only indi rect cost of removing the dam was referred to as the environmental costs of replacement electricity, which was estimated to be $5,000 to $8,000 per year. On the other hand, the net present value of benefits to recreational anglers would be $36.2 to $48.2 mil lion, indicating that removing Edwards Dam would significantly benefit the community.

Willingness to Pay for a Natural River

Several economic studies have assessed the public's willingness to pay to protect natural environments such as free flowing rivers.

For example, at one site in California a hydroelectric dam was proposed to provide power and drinking water. A survey was conducted in order to determine willingness to pay to preserve the natural state of a river.

The survey revealed that households were willing to pay $42 to $92 each per year to preserve the natural river. In contrast, the annual benefits received by these households from the project would have been just $2.64 per year. Clearly, it was in the best interest of the community to avoid the hydroelectric devel opment.[66]

In addition, there have been studies done on the value of general protection for natural rivers.

A study done by Sanders, Walsh, and Loomis[78] assessed the use and non use values of protecting rivers. They found that for rivers in Colorado, the total benefit estimated (use values plus non use values) was five times more than the estimate gener ated from only considering use values.

These results show that residents of Colorado find a significant benefit in preserving their rivers rather than using them for developments like dam projects. Table 16 illustrates the use and non use values for preserving the 15 rivers included in the study.

From this information, Sanders and others[78] esti mated the total net benefit of river protection over 50 years. The present value of total benefit from pro tecting the 15 rivers was estimated at $1,521 million (equal to $101.12 times the number of households).

The present value of the cost of protecting the rivers would be $69.5 million, which includes the opportu nity cost of foregone water development projects, management, and other opportunity costs. Thus, the total net present value of protecting the 15 Colorado rivers was estimated to be the difference, $1,451.5 million.

Table 16. Citizens Value River Preservation in Colorado

Willingness to pay per household for river protection, Colorado, 1983. The total value at the bottom of the table represents the total benefit (willingness to pay) each household receives from the preservation of 15 rivers including Poudre, Elk, Colorado, Gunnison, Green, Yampa, Piedra, Los Pinos, Conejos, Dolores, Encampment, Arkansas, Roaring Fork, South Platte, and Rio Grande.

Annual Household Values ($)	
Recreation use value	19.16
Preservation value	
Option value	15.97
Existence value	27.67
Bequest value	36.19
Total preservation value	81.96
TOTAL VALUE	**101.12**

Source: Sanders, et al., 1990.[78]

Appendix III: Glossary of Economic Terms

Benefit-cost analysis: a framework to assess proposed projects that applies value to the benefits and costs that would result from a project, indicating that the project should be undertaken if its benefits exceed its costs.

Bequest value: the value of knowing a resource is preserved for future generations.

Contingent valuation: a method of discovering peoples' willingness to pay (demand) in which people are simply asked how much they would be willing to pay for a certain resource, as opposed to studying peoples' behavior in order to infer their willingness to pay.

Cost-effective: the least expensive way of achieving a given environmental quality; or the way of achieving the greatest improvement in the environment for a given expenditure of resources.

Discount rate: a rate used to compare cost amounts over different time periods. It is used to determine how much a past or future dollar value will be worth today.

Existence values: the value of simply knowing that a resource exists.

Nonmarket: goods/services/resources not bought and sold, so not included in measurement of gross domestic product.

Non-use value: the benefit gained by people from a resource who are not actually using the resource.

Opportunity cost: the benefit lost by not choosing the next best alternative. It is the highest value alternative that is foregone. The lost opportunity is considered a cost of the chosen action.

Option values: the amount a person would be willing to pay to preserve the option of being able to experience the resource in the future.

Present value: money changes in value over time due to inflation; amounts of money at different periods in time cannot be directly compared with each other. Economists often figure out what the value of sums of money from different periods in time would be today the present value in order to accurately compare the values.

Use value: the benefit received by people who actually use the resource.

Willingness to pay: the amount a person is willing to pay for an environmental asset; willingness to pay also reflects a person's ability to pay.

Adapted from:

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This work was funded under Cooperative Agreement Number SRS 06-CA-11330139-222 between the USDA Forest Service Southern Research Station and Duke University.

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ABSTRACT

Under appropriate conditions, restoring wetlands on crop fields can result in a net increase of ecosystem services and therefore a net benefit to society. This study assesses the value of actions to restore wetlands via the Wetland Reserve Program (WRP) in the Mississippi Alluvial Valley (MAV) of the U.S. by quantifying and monetizing ecosystem services. Focusing on hardwood bottomland forest, a dominant wetland type of the MAV, *in situ* measurements of multiple ecosystem services are made on a land use continuum of agricultural land, wetlands restored via WRP, and mature bottomland forest. A subset of these services, namely greenhouse gas (GHG) mitigation, nutrient mitigation, and waterfowl recreation, are selected to be monetized with benefit transfer methods. Above- and belowground carbon estimates and changes in methane (CH_4) and nitrous oxide (N_2O) emissions are utilized to project GHG flows on the land. Denitrification potential and forgone agriculture-related losses are summed to estimate the amount of nitrogen prevented from entering water bodies. Increased Duck Energy Days (DEDs) on the landscape represent the WRP-induced expansion of waterfowl habitat. We adjust and transform these measures into per-hectare, valuation-ready units and then monetize them with prices from emerging markets (GHG) and environmental economic literature (GHG, nutrient, recreation).

Valuing all services produced by wetland restoration would yield the total ecosystem value of the change; however, due to data and model limitations we generate a partial estimate by monetizing three ecosystem services. Social welfare value is found to be between $1,446 and $1,497 per hectare per year, with GHG mitigation valued in the range of $162 to $213, nitrogen mitigation at $1,268, and waterfowl recreation at $16 per hectare. Limited to existing markets, the estimate for annual market value is merely $74 per hectare, but when fully accounting for potential markets, this estimate rises to $1,068 per hectare. The estimated social value surpasses the one-time public expenditure or social cost of wetlands restoration ($2,526 per hectare) in the MAV in only two years, indicating that the ecosystem service value return on public investment appears to be very attractive in the case of the WRP. Moreover, the finding that annual potential market value is substantially greater than landowner opportunity costs ($401–$411 per hectare) indicates that payments to private landowners to restore wetlands could be profitable for individual landowners in addition to being value-enhancing to society. This should help to motivate the development of ecosystem markets to more fully integrate societal values into land use decisions.

ACKNOWLEDGEMENTS

We would like to thank the U.S. Forest Service Southern Research Station for its support of this project, in particular the guidance and oversight of Dr. Patricia Flebbe. We appreciate the contributions made by David Shoch of TerraCarbon, Marc Ribaudo of USDA ERS, Ken Richkus of USFWS, Tom Moorman and Dale James of Ducks Unlimited, John Tirpak of the Lower Mississippi Valley Joint Venture, Lee Moore and Bruce McKenney of the Nature Conservancy, and participants in a workshop organized by the National Wetlands Research Center of the U.S. Geological Survey in Lafayette, Louisiana, in September 2007. We also are indebted to Marc Ribaudo for his insightful feedback on an earlier version of this report. Any remaining shortcomings in the study design are our own.

INTRODUCTION

In recent decades, U.S. agricultural policy has implemented programs that offer financial incentives to private landowners to spur restoration of natural habitat and its attendant ecosystem services. A younger sibling of the Conservation Reserve Program (CRP), the Wetlands Reserve Program (WRP) focuses specifically on the restoration, protection, and enhancement of wetlands on marginal farmland. Originally authorized in 1985, the acreage cap for WRP was expanded to 2.275 million acres in the 2002 Farm Security and Rural Investment Bill (USDA-NRCS 2007).

Ecosystem services, a collective term for the goods and services produced by ecosystems that benefit humankind, have traditionally been undervalued as they often fall outside of conventional markets and pricing (NRC 2005). Without market prices, the incentive to provide them privately has been low relative to other competing land uses, such as crops, timber, or mining. Furnishing evidence for this idea, the Millennium Ecosystem Assessment reported in 2005 that about 60% of global ecosystem services are being degraded or used unsustainably (MEA 2005). Increasingly, society has recognized the essential link between healthy ecosystems and human welfare and seeks ways to increase the provision of ecosystem services. Programs such as the WRP aim to stimulate provision of ecosystem services on private lands through strategic public payments to landowners and increased collaboration between landowners and government agencies. Also, substantial effort has gone toward the formation of nascent markets to allow the trading of new environmental commodities such as carbon offset credits (to mitigate greenhouse gases causing climate change) or water quality credits for land use actions that mitigate the introduction of nutrients and sediment to waterways. Economic valuation attempts to estimate the monetary values of these nonmarket ecosystem services so that they may be more fully accounted for in natural resource management decisions, both public and private.

An important dichotomy in economic values is that between social welfare value and market value. The first represents the economic value to society of the flow of ecosystem services and is the type of value which would be used in social benefit-cost analyses of public policies or programs. These social welfare values may pertain to varying geographical scales, as recreation is local, water quality is regional, and climate protection is global. Market value embodies what value landowners can capture through the market system and can be used to inform the design of landowner incentive programs for ecosystem protection or for the development of markets for ecosystem services. Market values encompass the goods, services, and assets traded in markets, ranging from traditional agriculture or land leasing to emerging commodities such as greenhouse gas (GHG) offsets.

This study focuses on the restoration of wetland ecosystem services in the Mississippi Alluvial Valley (MAV). The MAV covers the floodplain area below the confluence of the Mississippi and Ohio Rivers, principally located in the states of Arkansas, Mississippi, and Louisiana. Once containing nearly 10 million hectares (Mha) of bottomland hardwood forest, the MAV had only 2.8 Mha remaining by the 1980s following many decades of hydrological alteration and agricultural expansion (King et al. 2006). The major land use of the region is now agriculture, dominated by cultivation of corn, cotton, rice, and soybeans (USDA-NASS). This landscape transformation has had profound ecological consequences, such as wildlife habitat loss and fragmentation, loss of flood storage, and water quality degradation due to nonpoint source runoff.

The objective of the WRP is to restore and protect the functions and values of wetlands in agricultural landscapes with an emphasis on habitat for migratory birds and wetland-dependent wildlife, protection and improvement of water quality, flood attenuation, groundwater recharge, protection of native flora and fauna, and educational and scientific scholarship (USDA-NRCS 2004). The CRP has similar goals and objectives including improving the quality of water, controlling soil erosion, and enhancing wildlife habitat. The effectiveness of these conservation programs in achieving their goals and objectives, and thereby restoring ecosystem services, is not known for wetlands in the MAV. The USDA Conservation Effects Assessment Project (CEAP) began in 2003 as a multi-agency effort to quantify the environmental benefits of conservation practices used by private landowners participating in selected U.S. Department of Agriculture (USDA) conservation programs (Duriancik et al. 2008). As part of this program, the USDA CEAP-Wetlands component in the MAV has funded research on both natural forested wetlands and forested wetlands restored through the WRP and CRP. This research effort provides site-specific data on the ecosystem services supplied by these wetlands as well as by existing cropland. This data is used in valuation approach reported here.

This study aims to assess the value to society of actions to restore wetlands in the MAV. This objective is accomplished principally by comparing the economic values of ecosystem services produced on two land use types, agricultural land and restored wetlands. Constructing values from the bottom up, this study exploits a unique link between field data and economic valuation. Although the flows of ecosystem services are myriad, we confine ourselves to the three most well defined goods for the region's wetlands: GHG regulation, nutrient retention, and waterfowl recreation. The findings of this analysis can provide valuable input into public and private decision making regarding natural resource management, including an assessment of the impact the WRP. Methodologies and values developed here will be available for use by other regional wetland assessments as well as more broadly for ecosystem service studies undertaken elsewhere.

RELATED LITERATURE

Advances in ecosystem sciences in recent years have increased our understanding of the critical importance that healthy ecosystems play in environmental sustainability. Because of human impact on ecosystems, efforts to maintain and restore ecosystems require an improved understanding of how humans benefit from ecosystems as well as how human behavior can be influenced through conservation payments and other policy tools (Heal 1991; Kramer 2008). A growing body of research has examined ecosystem services and their valuation, and government agencies are searching for ways to incentivize the provision of ecosystem services (U.S. EPA 2002; Ricketts et al. 2004; Barbier 2007).

Economists have been measuring ecosystem service values for years, for example, as part of legal proceedings to assess and assign natural resource damages from oil spills and other environmental accidents (Carson et al. 1994; NRC 2005). Enthusiasm for ecosystem services, however, expanded to the broader scientific and policy community due in part to two widely influential works published in the mid-90s by Daily (1997) and Costanza et al. (1997). Costanza's article sought to estimate the economic value of earth's ecosystems in their entirety. Most economists since then have followed the counsel of Toman (1998) to focus on changes in specific ecosystem service flows, as does this paper. In that vein, Loomis et al. (2000) measure the total economic value of the restoration of five ecosystem services for an impaired section of the South Platte River. Using contingent valuation, the authors find that households interviewed would be willing to pay $252 annually for this restoration and that scaling those values to all living along the river produces an aggregate benefit estimate that exceeds the water leasing costs and CRP easement costs needed to realize the restoration. Despite describing the environmental services in the survey, the WTP question treats them as a composite, making it impossible to decompose values for individual services. In contrast, Chan et al. (2006) implement a conservation-planning framework to examine trade-offs between biodiversity and six other ecosystem services, but do not attempt to value the services economically. Their approach reveals spatial correlations between biodiversity and the production of ecosystem services and provides information on the relative impacts of different conservation targets on those services.

Two recent articles have conducted statistical meta-analyses of wetland valuation studies, using wetland value per unit area as the dependent variable. Woodward and Wui (2001) draw data from 39 studies, predominantly of temperate wetlands, while Brander et al. (2006) use 80 studies from 25 countries representing all the continents. Updating to 2008 U.S. dollars, the former found a mean annual value per hectare of $567 among its constituent studies, whereas the latter computed a mean of over $4,000/ha/yr but a median of $215. Significant decreasing returns to scale are noted as wetland area grows in both analyses, though Woodward and Wui (2001) assert that area has a minimal impact on value per acre because this effect rapidly approaches zero with increasing wetland size. Regarding the values of different wetland services, only bird watching (Woodward and Wui) has significantly higher value than average, while bird hunting and amenity services (Woodward and Wui) and hunting, material, and fuelwood services (Brander et al.) are found to be significantly lower than average. In each meta-analysis, the service nutrient retention is classified under water quality and GHG mitigation is not included at all. Both studies conclude that benefit transfer still faces major challenges and that the need for more high-quality primary valuation studies continues to be great.

A few studies have examined the benefits associated by the Conservation Reserve Program (CRP). Feather and Hellerstein (1997) evaluate the national benefits of reduced soil erosion for recreation by estimating the benefits in four study areas and then extrapolating them to the nation as a whole with a calibration function that accounts for area-specific factors. The authors report that 11%, or about $40 million, of the nationwide benefits are attributable to the CRP. Surveying both nationally and in Iowa, Ahearn et al. (2006) find that a conservative non-use value of the Central Plains grassland birds that increase in numbers due to the CRP to be about $33 million per year.

Anderson and Parkhurst (2004) consider farmers' decisions to continue commodity crop production or to enroll in the Wetland Reserve Program (WRP) in the Mississippi delta region. In their study, land was more likely to be entered into WRP if its crop base was soybeans/soybeans or cotton/soybeans and if it had considerable recreational value. In a similar analysis, Ibendahl (2008) simulates the farmers' decisions for three counties in Mississippi using crop budgets for 2008 which reflect the historically high crop prices. He concludes that the 30-year stream of crop returns and government payments for cotton or soybean production exceeds the expected per-acre WRP payment.

ECOSYSTEM SERVICE CONCEPTUAL MODEL

We are interested in estimating the value of ecosystem services associated with a change in the use of a given unit of land. Land is an asset that generates a flow of different services.

Some of the flow is in biophysical outputs that are directly sold in the agricultural market and perhaps the timber market. Other flows work though a series of ecological and spatial processes before they become part of a service that can be valued. For instance, nutrient retention is not a valued service per se; it becomes a valued service only after working through the hydrological system to create a change in water quality. Likewise, there can be complex relationships between the existence of a unit of a particular habitat in the area of interest and its relationship to what people value either locally or at a distance.

To describe the valuation process, we start with basic hedonic model (Rosen 1974; Palmquist 1989) of value, *V*:

$$V = V(a) \qquad [1]$$

where *a* = a vector of site attributes (e.g., size, soil quality, elevation, infrastructure, population, proximity to markets).

The ecosystem service flows are reflected in a vector, *S*, that is a function of the underlying attributes

$$S = S(a) \qquad [2]$$

The service vector *S* has three subvectors:

S_M(a): goods and services that can be sold in markets, (e.g., agricultural and forest commodities, housing, marketed ecosystem services such as hunting)

S_C(a): in situ goods and services consumed by the owner of the land (e.g., residential space, nonmarketed products, amenity values)

S_P(a): services that generate public goods that do not (yet) have markets (e.g., nutrient retention, biodiversity)

It should be noted that some of these services can be produced simultaneously on the same plot of ground (e.g., commodities and certain ecosystem services), while others require explicit choices and cannot be co-produced.

Hence, the flow value of land is expressed as the sum of the value of market and nonmarket services generated:

$$V(S) = p^*S_M + v^*S_C + w^*S_P \qquad [3]$$

where *p* is a vector of market prices matched with the market good/service vector, *v* is a vector of implicit prices reflecting the values of each self-consumed good/service, and *w* is a vector of implicit prices reflecting the marginal value to society of the public good/service vector generated onsite.

The market value of the land (rental) should reflect the array of market services generated in highest and best use. In other words, the prices of market goods and services and self-consumed goods will determine how the landowner chooses the level of market/consumed services that will be generated by the land (how much of marketed commodity, how much residential space, etc.). Hedonic value, as a function of attributes, is a reduced-form version of that $V = V(a)$. In other words, the site attributes are deemed to dictate the choices that determine the "highest and best use."

Hedonic models usually try to capture the relationship between market data (property values, which are a capitalized expression of the value flow, V) and attributes (a) to give marginal values of each. But here, given that there are no markets for the ecosystem services except those that have a market price or are self-consumed (in vectors S_M and S_C), hedonic valuation cannot help us determine ecosystem service values generated by the land. Because the market value does not capture all value, the market does not allocate to highest and best use. If all ecosystem services were valued in the market, then in principle it could.

So we can examine comparative values across discrete uses and see how optimal land allocation might occur if the market valued it (or if there were government intervention with payments for ecosystem services).

We are specifically interested in testing the hypothesis that the change in total economic land value increases as one changes from agriculture to wetlands:

$$H_O: V_W(a) > V_A(a) \qquad [4]$$

where $V_W(a)$ is the total value of land, inclusive of all ecosystem services whether marketed or not, when it is in wetlands and $VA(a)$ is the total value of land in agriculture.

As an economic principle, we believe that if land is in agriculture, then the sum of all marketed and self-consumed services in agriculture must be higher than the sum of all marketed and self-consumed services in wetlands, or any other use. The real issue, then, is whether the difference in public goods value exceeds the difference in market value.

Before proceeding, we acknowledge there are criticisms leveled at this "total economic value" approach to ecosystem services stemming from the fact that the estimated value is the sum of all measured services times their shadow price (see Howarth and Farber 2002 for a review of the arguments). The critical issue is whether it is reasonable to assume the shadow price remains fixed when the ecosystem service quantity changes. In standard economics terms, it is a matter of using a partial equilibrium approach for a general equilibrium problem. This is clearly problematic when the stock value of entire ecosystems is being valued, as presumably large changes in these services are at issue and prices (marginal values) would have to change. We do not believe this is a significant problem for this study. First, we are looking at changes in ecosystem services brought about by marginal changes in land use, not at the existence of entire ecosystems. The WRP, while an important public program, does not change the landscape at a scale large enough to fundamentally alter demand for the various services, and therefore has not likely changed the shadow prices either, or if they have changed, the change is small. Therefore, in our view, a more general equilibrium approach is not needed. However, one should be careful in interpreting the implications of these results for changes of a larger magnitude.

APPLICATION

Study Area

The Mississippi Alluvial Valley (MAV) is the nation's largest floodplain, extending from below the confluence of the Mississippi and Ohio Rivers to southern Louisiana (Figure 1). About three-quarters of the original bottomland hardwood forests have been converted, principally to row crop agriculture, while the remaining quarter is fragmented into over 38,000 discrete patches larger than 2 ha in size (Twedt and Loesch 1999). The study area encompasses all of the counties that intersect with the MAV, save for those in Louisiana bordering the Gulf of Mexico.

Figure 1. Extent of the Mississippi Alluvial Valley (MAV) and the locations of the 16 WRP sites sampled by USGS scientists.

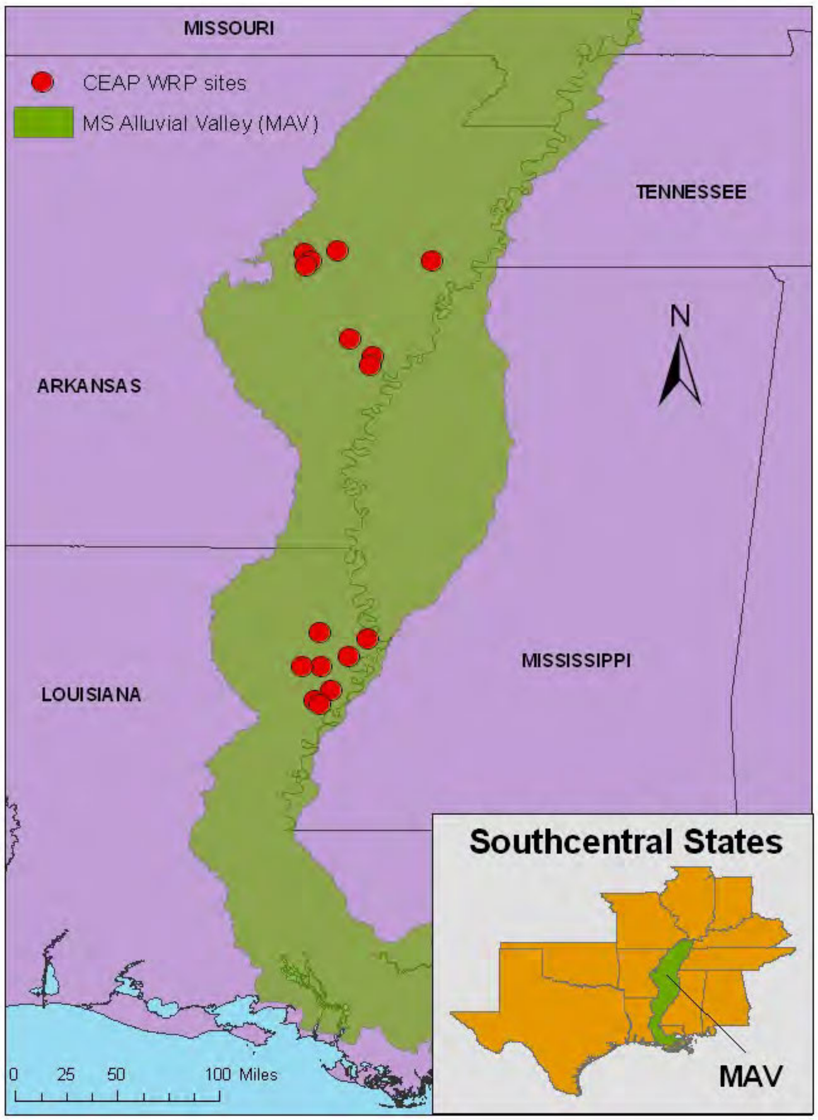
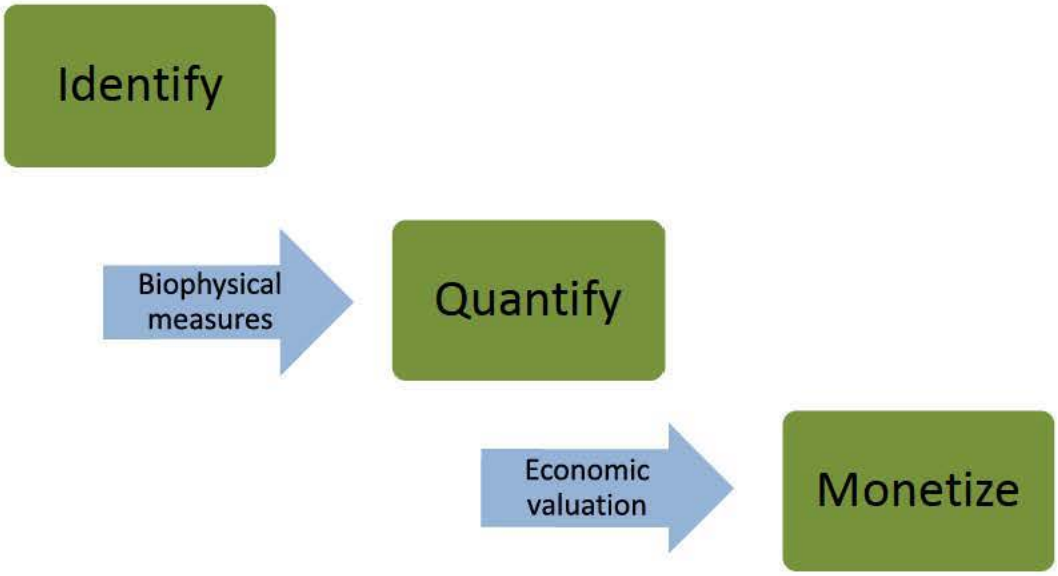


Figure 2. Flow chart of ecosystem service valuation process.



Benefit Valuation Process

There are three essential steps in the ecosystem service valuation sequence: (1) identify the service, (2) quantify the service flows, and (3) monetize those flows (Figure 2). Disciplines that assess biophysical processes, such as ecology, biogeochemistry, and hydrology, play the central role in moving from identification to quantification. Economics then provides the link from service quantification to monetization. Critical to bridging the biophysical and human aspects of ecosystem services is to transform the service flow data into valuation-ready measures. This transformation may involve integrating field observations with existing process models and modeling the service through time. We standardize the service measures into per-hectare values to facilitate comparisons with economic returns from other land uses and the aggregation of benefits to broader scales. Using benefit transfer methods (Wilson and Hoehn 2006), we multiply biophysical values for services of interest by shadow prices for the services (see conceptual model discussion). These prices are obtained either through market price observations or from estimates of marginal willingness to pay for these services in the environmental economics literature. We focus on the monetization of three services: GHG mitigation, nitrogen mitigation, and waterfowl recreation, which prior information suggests are the dominant service flows for the MAV region in terms of economic value.

Although new ecosystem markets are emerging, ecosystem services can generally be considered public, nonmarket goods. When valuing a nonmarket good, total economic value (TEV) is the sum of use values, which are directly or indirectly derived from the use of an ecosystem, and nonuse values, which are related to the ecosystem's existence (Krutilla 1967; Young 2005). Thus, the TEV is equivalent to the monetization of the flow of the services from an ecosystem. In the conduct of primary research, nonmarket valuation approaches tend to be divided into two main categories: (1) stated preference and (2) revealed preference (Freeman 2003). Stated preference methods use data of intended behavior derived from survey questions directly asking respondents how they would value differing levels of an environmental good. Contingent valuation and conjoint analysis are two examples of stated preference methods. Revealed preference methods utilize observed market prices, travel costs, and purchase decisions that are correlated with changes in an environmental attribute as indicators of value for that attribute. Examples include observed market prices for some services (e.g., GHG reductions, hunting leases), travel cost method for recreation values, hedonic property value studies, and estimation of avoided expenditures to achieve a certain level of an environmental attribute (e.g., water quality).

Acknowledging that time and resources are scarce, the benefit transfer method builds on the previous methods by applying results from primary research to new contexts of interest (Rosenberger and Loomis 2003). For example, the benefits estimated for a water quality improvement in one region may be adapted to estimate the benefits of an improvement in another region. A proper benefit transfer requires that the original study site be comparable to the targeted policy site with respect to the ecosystem service definition, the market (i.e., human population) context, and the welfare measure employed (Loomis and Rosenberger 2006).

In each application in this analysis, agricultural land use is treated as the baseline, since it represents the dominant land use in the MAV, and thus the business-as-usual scenario prior to restoration. Seeking to value the action of restoring forested wetlands on cropland, we capture this economic value by calculating the difference in the values of ecosystem services provided by the two respective land use types.

Biophysical Measurement of Ecosystem Service Flows

Scientists at the USGS National Wetlands Research Center carried out the sampling design and the data collection for this study as part of the CEAP-Wetlands component (Faulkner et al. 2008). Initiated in 2003, CEAP is a multi-agency effort to evaluate the effectiveness of conservation practices used by private landowners participating in selected USDA conservation programs (USDA-NRCSa). A major element of CEAP is the National Assessment, whose objectives are to collect national estimates of benefits resulting from conservation practices and programs for croplands, wetlands, wildlife, and grazing lands and to weigh the potential of existing and future conservation programs to meet the nation’s environmental goals. The wetlands component of the National Assessment measures the effects of conservation practices on ecosystem services provided by wetlands in agricultural landscapes and is being conducted in eleven regions throughout the coterminous U.S. These regional assessments will focus on one or more wetland hydrogeomorphic classes common to agricultural land in that region.

For the CEAP-Wetlands study in the MAV, a stratified random sampling design was used in the Lower White-Cache and Tensas river basins where eight replicate sites were selected for each of three treatments: restored to forested wetlands under the WRP, active cropland, and natural forested wetland sites. These sites are representative of the variability on the landscape and add up to 48 sites in total, 16 each of cropland, WRP, and natural forest. Site-level field data was collected between March and October 2006 for four ecosystem services, while soil samples for the denitrification measurements were taken in

2007. Three involve biogeochemical processes, namely, carbon sequestration, nutrient retention, and sediment retention, and the other two involve biological conservation, i.e., amphibian species richness and neotropical migrant bird species richness. Region-level data for migratory waterfowl habitat was calculated by estimating the extent of flooding based on Landsat Thematic Mapper (TM) classified image analysis for 2000–2005 and the estimated waterfowl foraging values of reforested areas (James et al., in review). Using the static chamber technique, methane and N_2O emissions were measured monthly from low- and high-elevation sites in both WRP and natural forested wetlands from 2005–2008 at 18 sites in the MAV different from the CEAP-WRP sites (Faulkner, unpublished data). Table 1 lists the relevant services with the metric measured and its spatial resolution.

Table 1. Ecosystem services measured by USGS National Wetlands Center and Ducks Unlimited.

Ecosystem Service	Definition/Metric	Spatial Resolution
Wildlife habitat – amphibians	Species richness (number/ha)	Site
Wildlife habitat – breeding birds	Species richness (number/ha)	Region
Wildlife habitat – waterfowl	Duck energy days/acre	Region
Nutrient retention	Denitrification potential (kg NO_3-N/ha/yr)	Site
Erosion reduction	Sediment (Mt/ha/yr)	Site
Carbon sequestration	Mg CO_2e/ha/yr	Site

ECOSYSTEM SERVICE VALUATION

Greenhouse Gas (GHG) Mitigation

Converting land from croplands to forested wetlands can affect the GHG balance in the atmosphere in several ways. First, carbon dioxide (CO_2), the most prevalent GHG, is removed from the atmosphere via photosynthesis and is sequestered in forest biomass and soils at levels typically well above the sequestration rate for crop systems. This creates a net carbon sink and reduces GHG concentrations, all else being equal. Second, crop production can be a significant source of non-CO_2 trace GHGs such as nitrous oxide (N_2O) and methane (CH_4), gases that are individually more potent than CO_2. Thus, discontinuation of agricultural practices reduces these emissions from the site. However, the anaerobic conditions of wetlands are ideal for the creation of methane and nitrous oxide and thus conversion can increase emissions accordingly. The net balance is determined by site conditions, as discussed below.

The process of converting GHG biophysical measures to monetary values is described below for carbon sequestration and non-CO_2 GHGs respectively.

Carbon sequestration

The biophysical data collected by the CEAP research team for this service are point estimates of aboveground and soil carbon in metric tons of carbon per hectare in the first few years after restoration. Because carbon accumulation in ecosystems is a dynamic process, these point estimate snapshots need to be transformed into GHG flux over time in order to be properly monetized. Carbon accumulation growth is tracked in three carbon pools—soil, live biomass, and other non-soil—and is projected for the future employing two different process models.

Soil carbon

For soil carbon sequestration, we average the soil carbon point estimates to create mean carbon values for all sites in each land use class (cropland, WRP land, and mature forest). Site soil carbon data are provided for the upper 15 cm of soil, where soil carbon is highest before decreasing dramatically with depth. These data are a fair proxy for one meter of soil depth, the standard used in soil carbon estimation. Next, we seed the WRP mean values, 20.83 Mg[1] C/ha/yr for Arkansas and 24.07 for Louisiana, into stand-level tables developed by the U.S. Forest Service as part of the federal 1605(b) GHG registry process. These tables are derived from the FORCARB2 forest carbon projection model (Smith et al. 2006). These tables contain data on carbon accumulation growth paths for afforested and reforested stands in 5-year increments by carbon pool, forest type, and U.S. region. To use the FORCARB2 soil model, WRP land in the MAV is proxied by afforested oak-gum-cypress forest in the south-central U.S. The growth paths are

[1] The abbreviation *Mg* stands for *megagram*; 1 Mg is equivalent to 1 metric ton (tonne) or 10^6 grams. This paper uses Mg except in the context of the carbon credit trading market, in which the standard abbreviation tCO_2e is used to refer to "metric tons of CO_2 equivalent."

traced out in 5-year time steps for 90 years from the initial year of restoration (see Table 2). Soil organic carbon at WRP sites is assumed to follow the same growth path as reported in the FORCARB2 lookup tables, though the beginning value is that provided by the CEAP field data.

Table 2. Growth and net carbon flux over 90 years in soil organic carbon for agricultural and WRP sites in Arkansas and Louisiana.

	FORCARB2 table	CEAP Data – AR		CEAP Data – LA		AR		LA	
		Ag	WRP	Ag	WRP	Ag	WRP	Ag	WRP
Age	Soil Organic Carbon					Carbon Flux			
yrs	Mg C/ha					Mg C/ha			
0	29.00		–		–				
5	29.10	20.80	20.83	21.84	24.07	0.00	0.00	0.00	0.00
10	29.40	20.51	21.05	21.54	24.31	−0.29	0.21	−0.29	0.25
15	29.80	20.23	21.33	21.24	24.64	−0.28	0.29	−0.28	0.33
20	30.40	19.95	21.76	20.95	25.14	−0.28	0.43	−0.28	0.50
25	31.10	19.68	22.26	20.66	25.72	−0.27	0.50	−0.27	0.58
30	31.90	19.41	22.84	20.38	26.38	−0.27	0.57	−0.27	0.66
35	32.70	19.14	23.41	20.10	27.04	−0.27	0.57	−0.27	0.66
40	33.50	18.88	23.98	19.82	27.70	−0.26	0.57	−0.26	0.66
45	34.30	18.62	24.55	19.55	28.37	−0.26	0.57	−0.26	0.66
50	35.10	18.36	25.13	19.28	29.03	−0.26	0.57	−0.26	0.66
55	35.80	18.11	25.63	19.01	29.61	−0.25	0.50	−0.25	0.58
60	36.40	17.86	26.06	18.75	30.10	−0.25	0.43	−0.25	0.50
65	36.90	17.61	26.41	18.49	30.52	−0.25	0.36	−0.25	0.41
70	37.30	17.37	26.70	18.24	30.85	−0.24	0.29	−0.24	0.33
75	37.60	17.13	26.92	17.99	31.10	−0.24	0.21	−0.24	0.25
80	37.90	16.90	27.13	17.74	31.34	−0.24	0.21	−0.24	0.25
85	38.10	16.66	27.27	17.49	31.51	−0.23	0.14	−0.23	0.17
90	38.30	16.43	27.42	17.25	31.67	−0.23	0.14	−0.23	0.17

At the agricultural sites, the initial soil carbon values come directly from the agricultural sites paired with the WRP sites in Arkansas and Louisiana. Conventional tillage is the assumed agricultural practice. In contrast to the WRP sites, agricultural soil carbon levels tend to gradually decrease over time as they are oxidized and released into the atmosphere as a result of crop production (Potter el al. 2006a). A 2006 NRCS study simulates the change in soil carbon content for agricultural lands over a 30-year time period with the Environmental Policy Integrated Climate (EPIC) model (Williams et al. 1989; Potter et al. 2006b). The analysis provides soil organic carbon estimates, as well as those for soil and nutrient losses, by region and by crop type.

Live biomass carbon

The non-soil carbon data from CEAP represents aboveground and belowground (i.e., coarse roots) live carbon biomass plus standing dead, understory, and forest floor carbon. Across the WRP forested wetland sites that had been planted between 4 and 12 years prior to sampling, non-soil carbon measurements average 2.70 Mg/ha in Arkansas (1.69–6.33 Mg/ha range) and 3.06 Mg/ha in Louisiana (1.79–5.71 Mg/ha range).

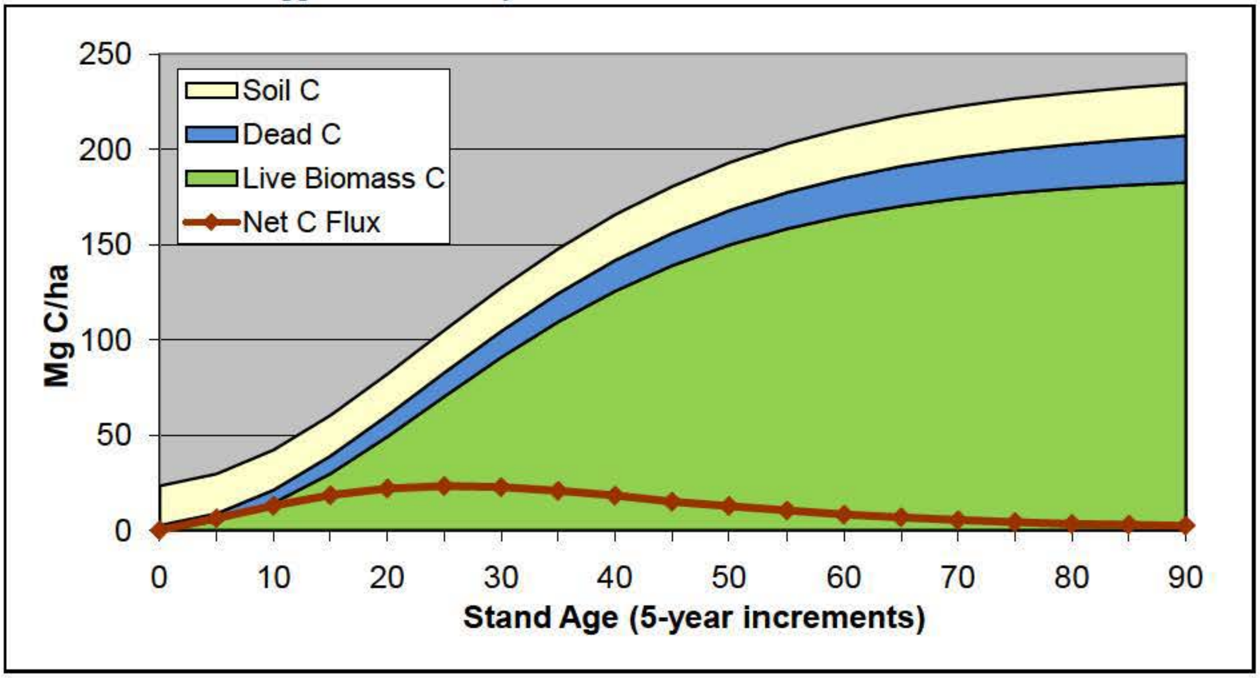
The majority of carbon sequestration potential resides in the growth of live carbon biomass (e.g., trees) through time, increasing from 72% at year 10 to over 86% in year 90 according to the USFS FORCARB2 tables (Smith et al. 2006). We estimate the carbon accumulation flows of this pool using the growth function from Shoch et al. (2008) who examine the carbon sequestration potential of bottomland hardwood afforestation in the MAV. The authors produce a chronosequence of even-aged plantations and naturally regenerated stands and statistically estimate a growth path that is markedly greater for years 20 to 90 than that derived from the USFS FORCARB2 tables for afforested oak-gum-cypress stands (Smith et al. 2006), which are commonly used for regional analysis.

This substantial difference between Shoch et al. and FORCARB2 is neither surprising nor a criticism of the FORCARB2, which is clearly defined as a model with large regional resolution. The estimated growth curve from Shoch et al. is specific to the MAV and is thus more appropriate for our study than the FORCARB2 tables whose estimates are for the south-central region in general. Dominated by bottomland red oaks, stem plantings in the WRP sites are very similar in species composition as the plantations surveyed by Shoch et al. (2008), further validating the use of their growth function. The CEAP field data for non-soil carbon falls approximately within the 95% confidence interval of and well within the prediction interval of the total live tree biomass carbon growth curve generated by Shoch et al. (2008). Therefore, it is appropriate to project future live tree carbon accumulation for the WRP sites with the Shoch et al. (2008) growth function.

Other carbon

MAV-specific estimates for carbon found in standing dead, understory, and forest floor (i.e., not found in live trees) are currently unavailable, so we utilize the USFS FORCARB2 tables as the best available source. Growth in carbon in those pools is projected in the same way as described above for the WRP soil organic carbon. In Figure 3, the carbon accumulation curve is depicted, with each major carbon pool represented by a different colored area.

Figure 3. Carbon growth and net carbon flux curves for afforested bottomland hardwood on WRP sites in Mississippi Alluvial Valley.



Carbon flux (Mg C/ha/time period) is the net change of carbon on the site from one period to the next so that positive carbon flux represents new carbon stored in addition to the existing carbon stock. This is the service flow of interest as it directly relates to the removal of CO_2 from the atmosphere, which provides the climate stabilization benefit. Flux often varies through time following the growth rate of the vegetation and soil carbon storage. The projected carbon flux for the WRP sites is represented by the red line in Figure 2. Agricultural sites (not shown here) have a slightly negative carbon flux, since soil carbon declines gradually from soil oxidation associated with crop production (Potter et al. 2006a) and the biomass grown in crops each year is also removed from the land on an annual basis. Once the carbon fluxes for total site carbon have been calculated for the agriculture and WRP sites, we then convert them into units of carbon dioxide equivalents (CO_2e) by simply multiplying by 3.67. CO_2e is the currency in which carbon service flows are monetized.

Non-CO_2 GHG emissions

The last step in quantifying the GHG sequestration potential is to account for the effect of emissions of trace GHGs, methane (CH_4), and nitrous oxide (N_2O). They have global warming potentials (GWP) much greater than CO_2 itself: 23 for CH_4 and 296 for N_2O (IPCC 2007). Both crop and wetland sites are net sources of CH_4 and N_2O emissions, though of different magnitudes. Accordingly, site N_2O and CH_4

fluxes are converted to their CO_2 equivalents using the GWP above, and are then subtracted from the CO_2 flux to determine the net GHG flux ($MgCO_2e$/ha/yr).[2]

For the agricultural sites in the region, CH_4 is emitted through rice production and residue burning and N_2O is emitted through the use of nitrogenous fertilizers and nitrogen fixation by soybeans. To find these GHG fluxes, we first determine the crop mixes for a representative agricultural hectare in the MAV for each state using data compiled by USDA National Agricultural Statistics Service (USDA-NASS). Then, we multiply the crop mixes by the corresponding state average estimates for agricultural CH_4 and N_2O emissions from the FASOMGHG model (Adams et al. 2005). Finally, weighted averages for the three MAV states are produced: −5.51 $MgCO_2e$ /ha/5 years for CH_4 and −3.14 $MgCO_2e$ /ha/5 years for N_2O.

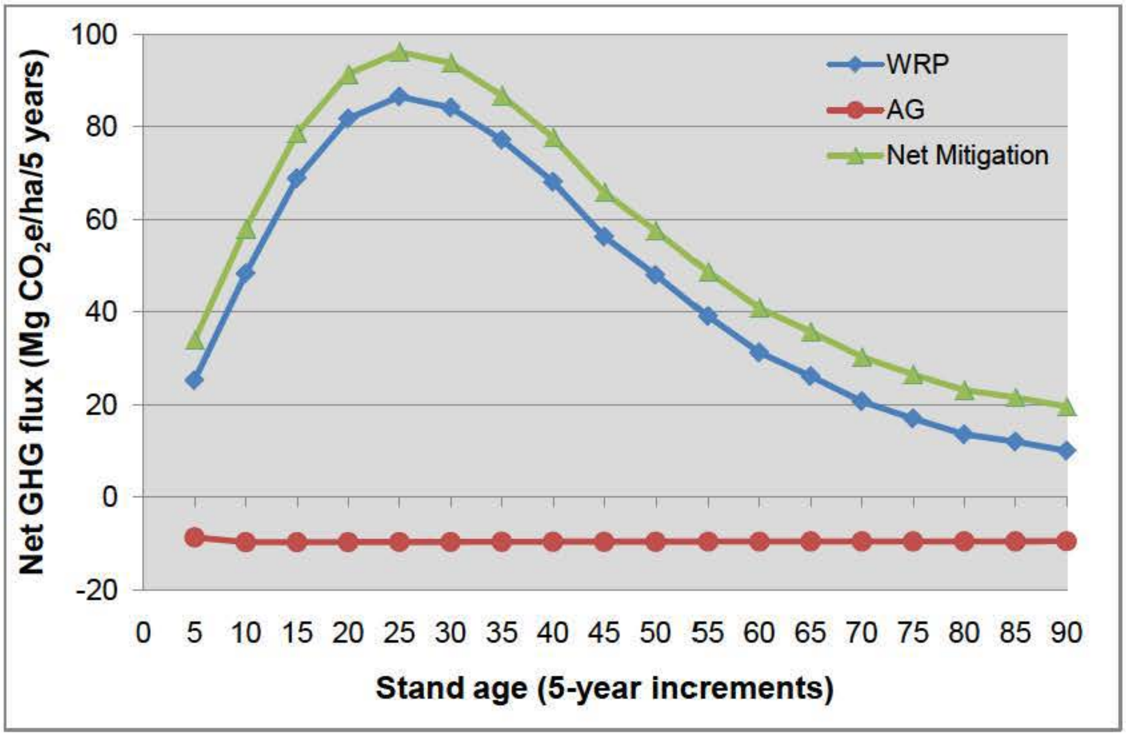
For both WRP and natural wetland sites, the levels of CH_4 and N_2O emissions vary by landscape position, i.e., whether the site is located in a low- or high-elevation position. Low-elevation sites flood more frequently and for longer duration than high-elevation sites and thus will experience longer periods with anoxic conditions in the soil. This anoxia is a prerequisite for the processes of methanogenesis and denitrification to produce gaseous methane and convert nitrate into gaseous dinitrogen (N_2) and nitrous oxide (N_2O) (Mitsch and Gosselink 2007). Since the goal of WRP is to remove frequently flooded, marginal croplands from commodity crop production, we estimate that approximately 80% of the WRP area is characterized by low elevation and the other 20% by high elevation. We multiply the CH_4 and N_2O emission rates for each landscape position by the corresponding proportion (0.8/0.2) and generate a weighted average of CH_4 and N_2O emissions for each 5-year increment between years 5 and 90 after the wetlands restoration. After converting to $MgCO_2$ equivalents, the mean CH_4 flux is −0.13 $MgCO_2e$/ha/5 years and the mean N_2O flux was −2.02 $MgCO_2e$/ha/5 years.

Total GHG flux change

Since a typical agricultural site candidate for restoration serves as the baseline, full GHG flux for restoring a hectare of wetland is the difference between the GHG fluxes for the average MAV agricultural and WRP sites. Figure 4 shows these three flux streams over the 90-year study period. Agricultural sites function as sources of GHG emissions and have a negative flux value for mitigation purposes (see footnote 2). In contrast, WRP sites serve as net sinks, have a positive mitigation flux value, and sequester up to 84 Mg of new CO_2 per hectare per 5-year period. Although non-CO_2 GHG gases are emitted in restored wetlands, their contribution is easily offset and exceeded by the carbon sequestration of the growing wetland forests. The net GHG mitigation value of restoring wetlands ranges between 19.6 and 96.2 Mg CO_2e/ha/5 years, with the peak coming at 25 years after planting the tree seedlings.

[2] We depart from some convention on the sign of the flux. We use the terrestrial ecosystem itself as the stock from which fluxes occur. Thus, a negative flux is an emission (e.g., release of CO_2 from oxidized soil carbon or the release of N_2O from denitrification), whereas carbon sequestration is a positive flux. We do this to highlight the notion that a positive number (increased sequestration or reduced emissions) is “mitigation” representing an environmental benefit that can receive a positive payment as discussed throughout.

Figure 4. Net greenhouse gas (GHG) mitigation from converting agricultural sites (AG) to WRP sites.



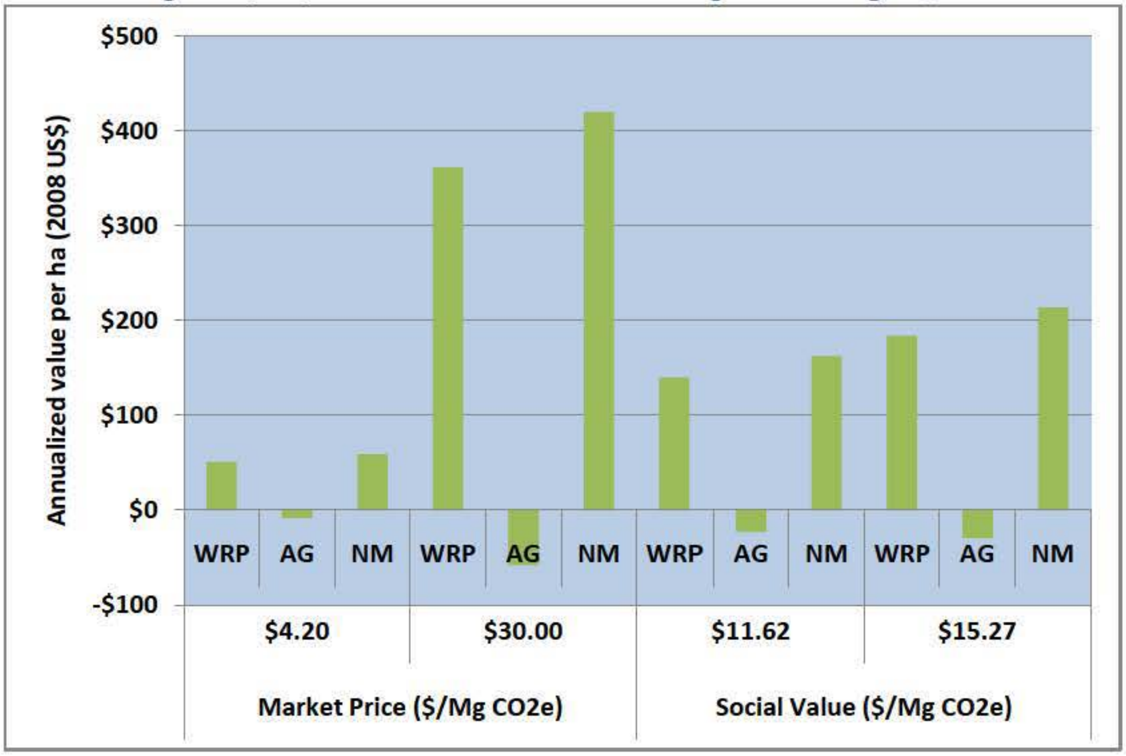
Monetizing GHG mitigation

The social welfare value of GHG mitigation captures the value of the damages avoided by mitigating the risks of climate change. This is typically estimated with the use of integrated assessment general equilibrium models to capture the *social cost of carbon,* or SCC. The IPCC Fourth Assessment Report (2007) reviews studies in the environmental economics literature that investigated the benefits of GHG mitigation and finds that mean estimates for SCC range from about \$12/MgCO_2 to \$15/MgCO_2. We use this as the shadow price for 1 Mg of GHG mitigated on our study sites.

Present value calculation

The stream of total GHG flux per hectare is multiplied by the market and social value prices and then discounted back to the present with a 4% real discount rate. The net present value of the GHG mitigation service is divided by the 90-year annuity factor to yield the annualized values per hectare that appear in Figure 5. Note that the discussion of how we determined the range of market prices used here is found further on in the Market Value section. The monetized net mitigation value is the difference between the WRP and agriculture sites. It ranges from \$59/ha/yr to \$419/ha/yr for the market prices of \$4.20 and \$30.00 respectively, while the social values are intermediate at \$162/ha/yr to \$213/ha/yr.

Figure 5. Annualized value per hectare in 2008 US$ for WRP, agricultural sites (AG), and net mitigation (NM) under market and social value prices for $MgCO_2e$.



Nitrogen Mitigation

Quantifying nitrogen service flows

Nitrogen is a major nutrient in agricultural runoff linked to water quality degradation in general (Carpenter et al. 1998) and, specifically, its increase in loading to the Mississippi River is considered a principal cause of the hypoxic "dead zone" in the Gulf of Mexico (Goolsby and Battaglin 2001). There are two principal ways in which wetlands restoration mitigates environmental damage from nitrogen releases: (1) forgone nitrogen (N) losses associated with runoff from crop cultivation and (2) removal of nitrate (NO_3) via denitrification.

When land is enrolled in a WRP easement, it is by definition taken out of agricultural production and thus the N losses driven by fertilizer application, fixation, and tilling cease. Because nitrate is the species of N most clearly correlated with the hypoxic zone size in the Gulf of Mexico, we focus on nitrate loading in our analysis (Mississippi River/Gulf of Mexico Water Nutrient Task Force 2007). We compute the nitrate prevented from entering the local waterways by applying average annual values for nitrate lost in surface water runoff, in lateral subsurface flow, and in leachate (N kg/ha/yr) from agricultural sites using output from the EPIC model (Potter et al. 2006b). These EPIC model estimates are available by U.S. region and by primary crop type within each region (Potter et al. 2006a). Knowing the counties in which the paired WRP and reference agricultural sites are located in the MAV but not their exact location due to privacy restrictions, we create representative crop sites for the MAV portion of each state with USDA data that details the crop mix for those counties (USDA-NASS). The nitrogen loss estimates for each crop type are combined with the crop type proportions to produce total nitrogen loss for a representative agricultural hectare in the MAV in that state. See Table 3 for an example calculation for Arkansas. Total nitrate ground- and surface-water losses for the MAV counties in Arkansas, Louisiana, and Mississippi are 41.3, 29.3, and 32.3 kg/ha/yr, respectively. Computed using the relative total hectares planted in crops in the MAV counties for each state, the weighted average of agriculture-related N loss for the MAV is 37.0 kg/ha/yr.

Table 3. Estimated nitrate loss by crop type from a representative agricultural hectare in the MAV in Arkansas.

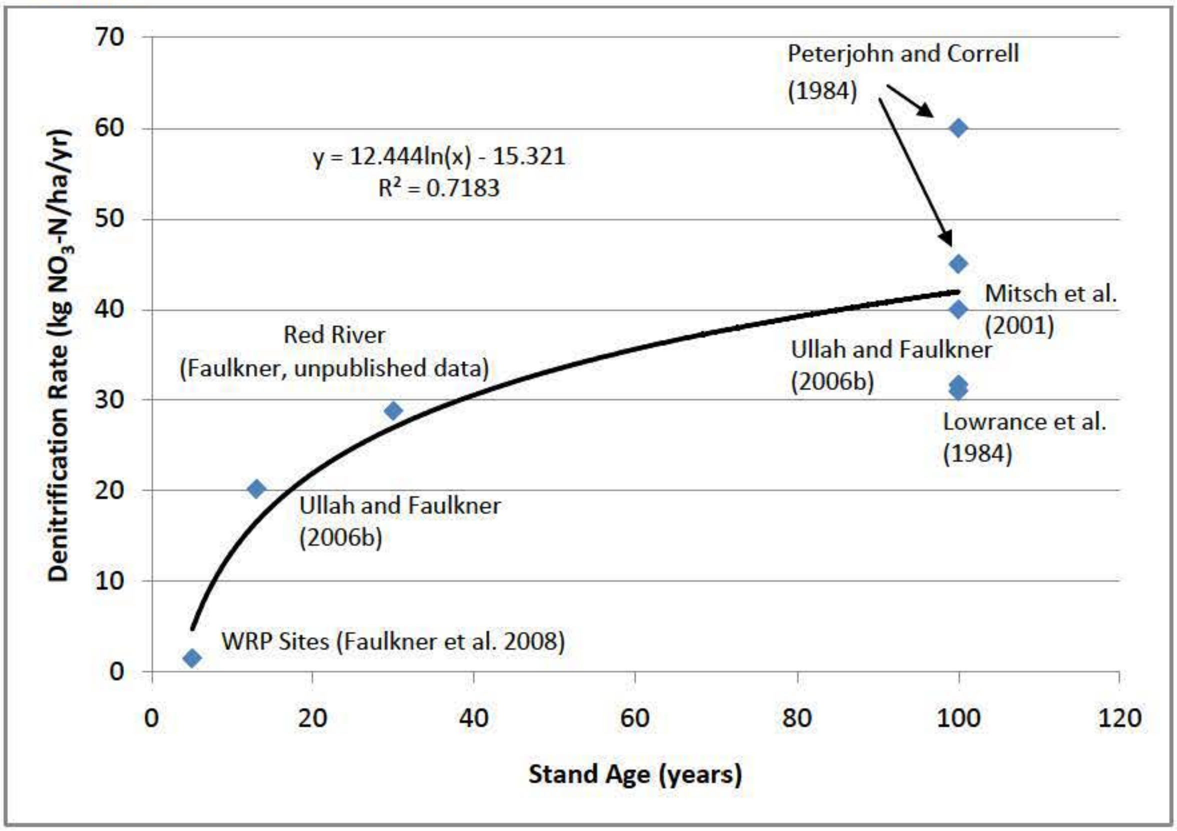
Crop Type	Estimated NO_3 Loss	Crop Type	Crop Contribution
	kg/ha	Proportion	kg/ha
Corn	24.9	0.031	0.8
Cotton	29.4	0.1	2.9
Rice	69.9	0.32	22.4
Sorghum	13.1	0.005	0.1
Soy	29.0	0.516	15.0
Winter Wheat	5.7	0.028	0.2
		Total	**41.3**

The second mitigation pathway is the removal of nitrate (NO_3) through the denitrification process, which is the primary N loss process in freshwater wetland ecosystems (Faulkner and Richardson 1989; Mitsch et al. 2001). The complex interactions of hydrology, soil type, nutrient loadings, and landscape position create the variability in specific ecosystem processes found in natural wetlands (even within a wetland type) and there is a wide range in reported nutrient retention rates due to differences in specific processes controlling those rates (Faulkner and Richardson 1989; Reddy et al. 1999; Novak et al. 2004; Lowrance et al. 2006). Reported denitrification rates in natural forested wetlands range from <1 to >800 kg N ha^{-1} y^{-1} (Mitsch et al. 2001, Lowrance et al. 2006). In addition, there is evidence that restored forested wetlands have different rates that change as the system ages and develops ecosystem characteristics more similar to forests than croplands (Hunter and Faulkner 2001; Ullah and Faulkner 2006a). This variability makes it difficult to predict N retention rates for WRP sites through time. We estimated denitrification potential (kg NO_3/ha/yr) with the denitrification enzyme assay (DEA) using field soil samples from both cropland and WRP CEAP sites. This denitrification potential approximates the rate at which nitrate is removed by the site. The DEA is a widely used approach (Groffman and Tiedje 1989; Clement et al. 2002; Ullah and Faulkner 2006a). We also reviewed published denitrification rates and found several studies that were similar to the WRP and natural sites evaluated here (Peterjohn and Correll 1984; Lowrance et al. 1984; Mitsch et al. 2001; Ullah and Faulkner 2006a, 2006b).

In order to capture the future denitrification potential of the restored wetlands, we modeled the relationship between the ages of forested wetland stands and the denitrification rates using the CEAP

WRP data; unpublished data from sites at Red River, Louisiana; and six point estimates from the literature. As can be seen in Figure 6, a log function fits the data well with a R^2 value of 0.7183. We use this curve to represent the age-dependent trajectory of denitrification through the 90-year study period at sites with a low landscape position. Since none of the published denitrification rates distinguish between low- and high-elevation sites in forested wetlands, we used experimental data which indicates that high-elevation sites display denitrification rates that are about 10% of those of low-elevation sites—low 28.8 kg N/ha/yr vs. high 2.88 kg N/ha/yr (Faulkner, unpublished data). Therefore, we assume that denitrification rates at high-elevation sites have the same trajectory as those at low-elevation sites, but with one-tenth of the value. Applying our assumption that 80% of the area of the WRP sites is low-elevation and 20% is high-elevation, we add together the proportional contribution of each site type to yield the combined N mitigated each year via the denitrification process.

Figure 6. Log function between measured denitrification rate and stand age of forested wetlands.



Nitrogen losses from agricultural land are a nitrogen source to the waterway, i.e., they have a negative mitigation value, while denitrification is considered a nitrogen sink, keeping N from entering the waterway and generating a positive mitigation benefit. Since restoring a wetland on cropland precludes additional agriculture-related N losses, those forgone losses are then seen as a positive mitigation value. We assume that forgone N losses from crop production remain constant through the study period so that annual N mitigated equals the forgone N losses (37.0 kg N/ha/yr) plus the current level of denitrification. Because the agricultural site functions as the baseline, the nitrogen eliminated through denitrification there must be netted out to arrive at the N mitigated due to WRP wetlands restoration. It is assumed that the denitrification rate on cropland does not "mature" through time and so the constant mean value for the 16 CEAP agricultural sites, 1.69 kg N/ha/yr, is subtracted annually.

Figure 7. Nitrogen (N) flux accounting for MAV counties over the 90-year study period. DP is denitrification potential, WRP is the WRP sites, and Ag is the agricultural sites. Low is low elevation, High is high elevation, and Wtd Avg is 80% low, 20% high.

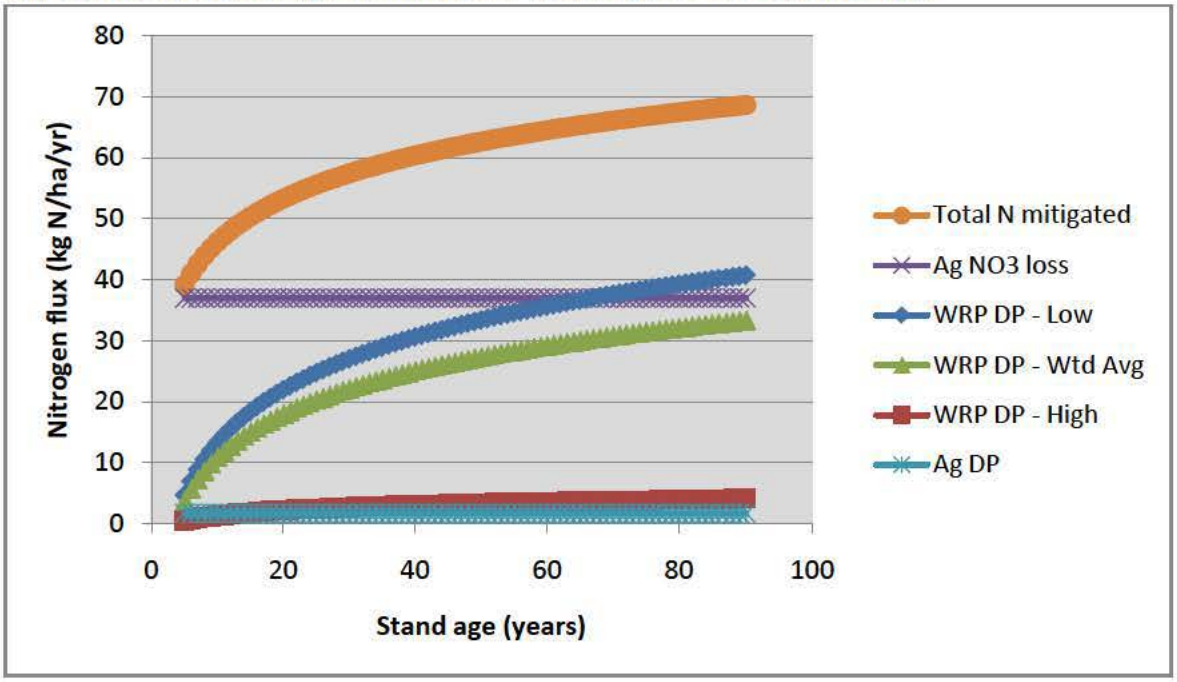


Figure 7 depicts the curves of denitrification rates for WRP low, high, weighted average, as well as for agriculture sites; the N losses associated with crop production; and the total N mitigated. Total N abatement is dominated by the cropland N loss pathway in the years immediately after a wetland restoration takes place. As the wetland grows, the contribution of denitrification to total N mitigated rises from 10% at year 5 to nearly 49% by year 90. Total N mitigated increases from about 37 kg N/ha/yr in the early years to almost 69 kg N/ha/yr by the end of the study period.

Monetizing nitrogen mitigation

Nitrogen mitigation is monetized using a price estimated for the Delta region (Arkansas, Louisiana, and Mississippi) of the U.S. South in Ribaudo et al. (2005). That study's results are selected for the benefit transfer because it is one of the few studies in the literature that produces a marginal price for nitrogen mitigation; moreover, its estimates are also specific to the MAV study area. Note that its values are only for the wastewater treatment industry.

Ribaudo et al. (2005) employ the U.S. Agricultural Sector Mathematical Programming (USMP) model to explore the potential for nitrogen credit trading in the entire Mississippi Basin by modeling the interaction between agricultural nonpoint sources and wastewater treatment plant point sources mandated to reduce nitrogen emissions. In the model, farmers are able to furnish nitrogen reduction credits via the following four methods: changing fertilizer application rates, changing production practices, growing different crops, or retiring cropland. Restoring wetlands is not included as a mitigation option because, in an earlier paper, Ribaudo et al. (2001) demonstrate that wetlands restoration is generally more expensive than fertilizer management and therefore a less attractive alternative for farmers. However, the cost of the alternative approaches does capture the avoided costs of achieving the given level of water quality improvements in another way when wetlands restoration is undertaken in the region, and thus provides a workable marginal value for wetland N mitigation outcomes.[3]

Table 4. Annualized value of N mitigation service and range of values depending on costs of marginal N credits in Ribaudo et al. (2005) (all values are in 2008 US$).

	Cost of marginal N credit ($/kg N)	Net Present Value	Annualized value ($/ha/yr)
Study area	$25.27	$30,773.76	$1,268.12
Lower bound	$22.82	$27,790.15	$1,145.17
Upper bound	$106.09	$129,196.20	$5,323.89

The cost of the marginal trade for the Delta region is estimated at $10.50/lb N, a result which we transform to $25.27/kg N by converting it to price per kilogram and then by inflating the price to 2008 dollars using the CPI Inflation Calculator (BLS 2008).[4] For the dynamic model of nitrogen mitigation developed here, the monetization step follows the same process as applied to the GHG mitigation service. Each year the amount of total nitrogen abated is multiplied by $25.27/kg N. Next, the 90-year stream of N mitigation values are discounted back to the present using a 4% discount rate and then converted to an annualized value. The result is over $1,268/ha/yr. A range of values for N mitigation is derived by using the lowest and highest N credit prices among all sub-regions in the Mississippi Basin generated by Ribaudo et al. (2005). In Table 4, the costs of a marginal N credit range from $22.82 to $106.09 kg N and the interval of annualized values is between $1,145 and $5,324. The costs to mitigate nitrogen in the MAV are clearly at the low end of the range and may therefore represent a relatively conservative estimate for the valuation of nitrogen mitigation service.

Wildlife Habitat Service

Converting row crop fields to wetlands results in additional habitat for many taxa of wildlife, including anurans (i.e., frogs), black bear, and neotropical migratory birds. Although habitat benefits accrue to a variety of wildlife in the MAV, our analysis focuses on the benefits from the expansion of migratory waterfowl habitat by WRP. This is in large part due to the widely recognized recreational value derived from waterfowl, which has generated values in the economics literature, enabling benefit transfer

[3] We recognize that replacement cost is conceptually a less-preferred shadow price than a directly estimated WTP value for the service, but unfortunately there are no direct estimates of WTP to draw from. We do believe replacement cost is an empirically valid measure for the region because policies are attempting to take a suite of approaches to achieving certain water quality targets for the region (Mississippi River/Gulf of Mexico Water Nutrient Task Force 2007).

[4] As a comparison, the Nutrient Offset Program run by North Carolina's Ecosystem Enhancement Program uses $21.67/lb N for the Tar-Pamlico River Basin and $28.35/lb N in the Neuse Basin ($47.77/kg N and $62.50/kg N) for offset payments to mitigate nitrogen (http://www nceep.net/services/stratplan/Nutrient_Offset_Program htm).

(Duffield and Neher 1991; Gan and Luzar 1993). Alternatively, marginal increases in anuran species or in black bear habitat have not been previously monetized.

Quantifying waterfowl habitat service flows

Flooded bottomland forests provide necessary forage for waterfowl that overwinter in the Mississippi Alluvial Valley as well as for those who stop over in the MAV en route to other wintering grounds such as Mexico (LMVJV Waterfowl Working Group 2007). Other benefits include protection from winter weather and pair isolation habitat (Baldassarre and Bolen 2006). We concentrate on the food provision aspect of these WRP wetlands which is captured by the metric Duck Energy Days (DEDs). A DED represents the amount of daily energy required by a duck supplied by a unit area of foraging habitat for a day (Reinecke and Kaminski 2007). The DED value of 294.35 kcal reflects the "average duck" wintering in the MAV, thus taking into account daily energy requirements of all dabbling ducks, of which mallards are the most common, and also of wood ducks (LMVJV Waterfowl Working Group 2007). The difference between DEDs produced on restored wetlands and on cropland is equivalent to the additional waterfowl habitat provided by WRP.

To calculate the net gain in waterfowl habitat, we first draw on the results of James et al. (in review). For the MAV areas of Arkansas, Louisiana, Mississippi, James et al. calculate the DEDs on post-restoration WRP lands, on the pre-restoration cropland, and the net DED increase for the 110-day wintering period. These calculations are based on an analysis of the flooding frequency of WRP acreage and the DED values per hectare for pertinent land use classes for WRP land (e.g., 677 DED/ha for naturally flooded restored wetland) and cropland (e.g., 89 DED/ha for harvested flooded soybean fields). In Table 5, we report the DED averages for each state over the 2001–2005 time period. The post-restoration net increase in DEDs is then divided by the total DEDs estimated to be produced in the MAV on all public and private land (LMVJV Waterfowl Working Group 2007). The quotient is the gain in DEDs in the MAV due to WRP-driven wetlands restoration, averaging 9.19% across the three states.

Table 5. Waterfowl habitat impact of wetlands conversion in duck energy days (DEDs).

State	Hectares WRP, avg 2001-2005	WRP: Post-restoration DEDs	Baseline: Pre-restoration DEDs	Net DED Increase post-restoration	Total DEDs in MAV, avg 2001-2005	DED Increase due to WRP in MAV
Arkansas	48,158	18,449,659	1,241,126	17,208,533	226,379,794	8.23%
Louisiana	65,673	10,923,441	804,859	10,118,582	132,498,674	8.27%
Mississippi	49,231	14,177,318	993,564	13,183,754	122,512,518	12.06%
Total	**163,062**	**43,550,418**	**3,039,549**	**40,510,869**	**481,390,986**	**9.19%**

The final step in this quantification process involves linking gains in waterfowl habitat to changes in hunting behavior. Increases in waterfowl habitat generally mean augmented hunting opportunities. That is, more habitat implies potentially more waterfowl in the MAV and thus a greater population to hunt. One caveat is that these waterfowl populations are migratory and thus dependent on habitat in more than one region to thrive. In particular, the prairie pothole region in the north-central U.S. and south-central

Canada serve as the most important breeding ground for North American ducks, producing 50% to 80% of the continent's duck population (Batt et al. 1989). The MAV is part of a waterfowl network called the Mississippi Flyway, whose duck populations principally originate in the prairie pothole region. Waterfowl habitat gains in the MAV represent greater resource flow in the region and create a positive network externality, though these benefits may be potentially moderated or even offset by changes in other components of the habitat network. Without modeling the entire breeding and migration network of North American ducks, our results will have to serve as a reasonable first order estimate of the region's contribution to hunting opportunity.

Greater waterfowl population numbers can result in increased harvest rates for hunters (a quality effect) as well as induce more waterfowl hunting trips (a quantity effect). More habitat provided by private land in WRP easements could also furnish additional destinations for hunting trips and thus potentially more trips (a quantity effect). We endeavor to capture these effects through a quantity measure, duck hunter days afield. A direct relationship is assumed between the percentage of increased waterfowl habitat created via WRP and the percentage increase in duck hunter days. Ideally, gains in hunter days are computed by multiplying the average numbers of duck hunter days in the MAV counties of each state for the five seasons between 2001 and 2005 by the percentage of waterfowl MAV habitat increase in the corresponding state over that same time period. Since duck hunter days are not available at the sub-state level, we use five-year averages of U.S. Fish & Wildlife Service county-level data on duck harvests to find the share of state harvest occurring in the MAV counties of the three states. These shares are then multiplied by the average number of duck hunter days in each state (2001 to 2005 seasons) to yield the number of duck hunter days in the MAV for each state (USFWS 2003; USFWS 2004; USFWS 2006). It should be noted that those percentage changes in duck hunter days, although not trivial (between 8% and 12%), are still marginal and thus appropriate for our economic valuation approach.

Table 6. The calculation of increase total surplus per hectare due to increase in waterfowl habitat in the MAV due to the Wetlands Reserve Program (WRP).

State	Increase in habitat due to WRP	Waterfowl Hunter Days in MAV, avg 2001-2005	Increase in Waterfowl Hunter Days	Total increase in consumer surplus	Consumer surplus gained per ha	Producer surplus gained per ha	Total surplus per hectare
Arkansas	8.23%	415,185	34,157	$1,655,944	$34.39	$15.00	$49.39
Louisiana	8.27%	109,383	9,044	$438,452	$6.68	$15.00	$21.68
Mississippi	12.06%	86,196	10,394	$503,910	$10.24	$15.00	$25.24
Total/Avg	**9.19%**	**610,764**	**53,595**	**$2,598,307**	**$15.93**	**$15.00**	**$32.10**

Monetizing waterfowl service flows

To monetize the change in the ecosystem service of waterfowl habitat, we consult the recreation economics literature for an appropriate value of an additional day of waterfowl hunting to be used as the transferred shadow price. For the per-day value of waterfowl hunting, we take the results of a meta-analytical study on outdoor recreation values conducted for the U.S. Forest Service (Rosenberger and

Loomis 2001). The value estimated for the southeast region was $34.72 in 1996 dollars, which we update to $48.48 in 2008 dollars by using the CPI calculator (Bureau of Labor Statistics 2008). Therefore, the total increase in consumer surplus resulting from WRP is the estimated increase in waterfowl hunter days multiplied by $48.48. Consumer surplus gained per hectare of restored wetland is simply the total increase divided by the number of hectares in WRP easements in each state. These values range from about $7/ha/yr to $34/ha/yr, with an average of $16 across the three basins. Using $15/ha/yr as the average producer surplus obtained (discussed below), that value can be added to the consumer surplus gains to yield total annual surplus values of between about $22 and $49 per hectare, with a mean of $32 across the MAV.

Total Social Value of Ecosystem Services: Partial Estimate

Summing the results from the preceding three ecosystem services valuation applications attains a partial estimate for the total ecosystem value of wetlands restoration (see Table 7). Although they were not monetized in this analysis, it is assumed that floodwater storage, sediment retention, and other habitat services also possess positive economic values. Therefore, the total social value estimated here, which ranges from $1,446/ha/yr to $1,497/ha/yr, is necessarily a lower bound on the full social value of restoring wetlands.

Table 7. Social Welfare Benefit estimates of individual ecosystem (estimates in 2008 US$/ha/yr).

Ecosystem Service	Social Value ($/ha/yr)
GHG mitigation	$162–$213
Nitrogen mitigation	$1,268
Wildlife recreation	$16
Total	**$1,446–$1,497**

As we will discuss below, the social value estimate for wetlands restoration dwarfs the market value that exists with current markets, being almost 20 times greater. However, we will first examine how it is that not all of these social welfare values can be captured in markets for the private landowner.

Market Value

The estimates in the section above are measures of social welfare value and are thus appropriate to use for social benefit-cost analysis to gauge the performance of public programs such as WRP. However, the emergence of ecosystem service markets raises the question of whether private markets can play a role in incentivizing socially beneficial landowner behavior. Thus, we turn to an assessment of market value with the potential to be captured by landowners in the region.

GHG mitigation

Market value for GHG mitigation is realized through the existence of carbon markets for GHG mitigation, wherein landowners can be compensated for sequestering carbon or reducing emissions below a baseline as part of an offset program in a cap-and-trade system. In 2008, carbon credits were traded as an environmental commodity on the voluntary Chicago Climate Exchange (CCX) in the range of $1.00 and $7.40/tCO$_2$e. We use the midpoint of this range, $4.20/tCO$_2$e, for the low market price in the analysis. Because voluntary demand is generally less binding than a mandatory system, this price is relatively small. Prices on the European Union Emissions Trading Scheme (EU ETS), part of the Kyoto Protocol compliance driven market have been much higher, near $35/tCO$_2$e in the summer of 2008, but we do not use its values because the ETS does not allow forest carbon in its trading. Instead, we draw upon the analysis of the recently proposed Lieberman-Warner climate change bill (S. 2191), which calls for a federal cap-and-trade program covering the energy, transportation, and industrial sectors with mitigation from the forest sector usable as offset credits for the capped sectors. Various estimates of the Lieberman-Warner bill estimated a carbon price of about $20/tCO$_2$e to $30/tCO$_2$e. We use $30/tonne as the upper end of the market price range. In Table 8, annualized values per hectare for GHG mitigation are calculated to be about $59 for the low market price and over $419 for the high market price.

GHG offset payments in forestry and agriculture typically have to be modified to account for permanence, additionality, and leakage (Murray et al. 2007). Permanence reflects the fact that stored carbon could be re-released due, for instance, to harvesting the timber after some time. Seeing that the majority of WRP easements in our study area are permanent, we assume that the converted wetlands will not be harvested and thus we make no adjustment for impermanence. Additionality adjusts for the fact that some of the activity getting credited may have happened anyway without the payment. This is unlikely in the case of hardwood restoration in the MAV, as afforestation rates are extremely low there without any kind of government inducement. So no further adjustment is made. Leakage means that GHG sequestration services gained in one area are partially compensated by loss in another. This can happen when restoring cropland to wetlands in one place could cause land clearing for agriculture in another. Leakage rates have been estimated at 43% for forest carbon sequestration programs in the south-central region (Murray et al. 2004). Studying 12 states in the central U.S., Wu (2000) found that about 20 acres of non-cropland was converted to cropland for every 100 acres enrolled in the Conservation Reserve Program (CRP). Nevertheless, although ecosystem service values determined here may be offset by leakage elsewhere of the system, perhaps by as much as 20% to 40%, the direct estimation of that leakage effect is outside the scope of this study. Therefore, following the protocol used by the Chicago Climate Exchange for Afforestation Offset projects(Chicago Climate Exchange 2007)., we present the calculated GHG flux values (and all other ES values estimated here) without adjusting for leakage.

Nitrogen mitigation

Although there are more than 40 nutrient trading programs on the books in the U.S., very few trades have taken place to date (Ribaudo et al. 2008). As such, the market value under existing markets is essentially zero for N mitigation. Nevertheless, given the substantial interest in nutrient trading and the degraded condition of many of the nation’s waterways, it is not implausible that N abatement will gain a market value in the near future. It should be noted that the potential market value of the nitrogen mitigation service equals only half of the social value because we assume that a nutrient trading scheme would require a trading ratio of at least 2:1. The most common ratio for trading between point and nonpoint sources is 2:1 (Morgan and Wolverton 2005). That is, two kilograms of nitrogen needs to be mitigated by farmers for every one kilogram of nitrogen credit generated. Ratios are used in order to reduce the uncertainty involved with nutrient mitigation by nonpoint sources such as farms. Therefore, we estimate an annualized potential market value of $634/ha/yr for nitrogen mitigation.

Waterfowl recreation

In addition to the consumer surplus accruing to regional waterfowl hunters, private landowners who enroll in WRP may also potentially garner some level of producer surplus. Since easements necessarily occur on private land, WRP participants can be seen as producers of the waterfowl habitat and could capture a portion of the created value through hunting leases. Recent studies in Mississippi find that hunting lease prices range from $4 to $8 per acre per season, or about $10 to $20 per hectare (Hussain et al. 2007; Rhyne and Munn 2007). Using the mean of these findings, the annual market value for waterfowl recreation is $15 per hectare.

Table 8. Benefit estimates of individual ecosystem services for market value, assuming current markets, or considering potential markets (estimates in $2008/ha/yr).

Ecosystem Service	Market Value – Current markets	Market Value – Potential markets
GHG mitigation	$59	$419
Nitrogen mitigation	$0	$634
Wildlife recreation	$15	$15
Total	**$74**	**$1,068**

Market value summary

Given current markets, market value yields about $74/ha/yr and pales in comparison to the estimated social value of over $1,400/ha/yr. However, the gap closes to a large degree when one considers potential markets for ecosystem services. At $1,068/ha/yr, the potential market value is about three-quarters of the social value and over 14 times the market value under existing markets. Nitrogen mitigation is clearly the driver for both of the larger values, comprising 59% of the potential market value and almost 90% of the social value.

COMPARISONS WITH COSTS OF WETLAND RESTORATION

To provide context for the above estimates of ecosystem service benefits, we examine the two types of costs related to their provision. The first is the private cost borne by the landowner, and the second is the social cost of implementing WRP shouldered by the federal government. We do not attempt to conduct a full cost-benefit analysis, which would imply a complete accounting of all costs and benefits of wetlands restoration. For ease of comparison with the estimated benefits, costs are converted to per-hectare units.

Landowner Perspective

From the perspective of the MAV landowner, the main opportunity cost of wetland restoration is the forgone income from agricultural use of the land. We can estimate this cost by considering either annual cash rents for agricultural land or the net returns from crop production. For the three Delta states, average cash rents per hectare range from $138 to $209, with a mean of $169 (USDA-NASS 2006). Looking at crop production in the region, returns vary substantially by crop type and by year over the period of 1997 to 2006. After subtracting operating costs from the value of production, rice emerges as the most profitable at an average of $391 per hectare, while wheat is the least at an average of $141 per hectare (USDA ERS). Using the representative agricultural hectare approach described in Nitrogen Mitigation Service subsection, we find that the annual return for a hectare of crop production in the MAV is $277.

Another relevant source of income for agricultural producers is government payment programs. The 2002 Farm Bill furnishes three types of payments to farmers, of which only the direct payment is provided annually and is independent of the crop cultivated (Ibendahl 2004). The provision of the countercyclical and loan deficiency payments hinges on national and county crop prices and is not guaranteed each year. Focusing on the Mississippi Delta, Parkhurst and Anderson (2004) calculate that the sums of the direct and maximum countercyclical payments per base acre are $17 for soybeans, $156 for rice, and $139 for cotton. The corresponding values per hectare are $42, $385, and $343. Ibendahl (2008) finds that for three Mississippi counties, expected government payments for cotton and soybeans average $133 and $25 per acre, respectively ($329 and $62 per hectare). Applying these values to the representative agricultural hectare approach, we obtain a conservative estimate of about $91 per hectare.

Using $277 as the value of a hectare for crop production and $91 as the annual government payment subsidy, their sum of $368 represents the estimated annual per-hectare income forgone by a private landowner who opts to enroll acreage in the WRP. If the landowner wished to undertake a wetlands restoration on his property without enrolling in a conservation program, one-time costs for afforestation projects in the MAV may run around $680 to $900 per hectare.[5] Assuming that those restoration costs are

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[5] NRCS costs for restoring a forested wetland in Arkansas are approximately $275 per acre ($680 per hectare) (personal communication, Andrew James 2009). A private firm specializing in afforestation projects may charge around $350–$375/acre ($865–$926/hectare) for a carbon offsets package that includes the basic site preparation and tree planting, as well as “long-term carbon monitoring plan, with initial funding price inclusive of permanent monitoring plot establishment, soil carbon measurement and baseline report, 100-year carbon reporting table, and survival analysis during the third growing season,” plus “guidance on offset registration and standards” (personal communication, Carol Jordan 2009).

paid up front, a present value analysis combining foregone agricultural income with the restoration costs over a 90-year horizon yields an annualized value of $400 to $411. Currently the annual market value that could be captured from existing carbon and hunting markets amounts to $74 per hectare, only about a fifth of the net returns from agricultural production. In contrast, the potential market value of GHG mitigation, nitrogen mitigation, and wildlife habitat provision with emerging ecosystem markets is $1,068—over two and a half times greater than the restoration opportunity costs. Without the payments provided by WRP, landowners will not have sufficient economic incentive to undertake wetlands restoration on their properties until markets for environmental services become more fully developed.

Taxpayer Perspective

The principal costs to taxpayers of restoring wetlands via the WRP are the easement payments to landowners and the cost share of the restoration. Easement payments provide compensation to the landowner for forgoing agriculture and are made as a lump sum in the first year of the WRP contract. Under a 30-year easement, the USDA pays for 75% of the restoration cost, whereas it covers 100% of the cost for a permanent easement (USDA-NRCS 2007). The publically available cost data for the WRP aggregates the annual costs for all three contract options at the state level for 2003 to 2007 (USDA-NRCSb). From this data, we can derive per-hectare costs incurred by the USDA for each state. The 5-year average across the three Delta states is $2,617 per hectare in 2008 dollars. Since the government no longer is obligated to provide agricultural payments when a farmer enrolls land in WRP, the annual subsidy estimated above ($91) should be subtracted from the WRP cost. We use the remainder of $2,526 per hectare as the one-time public expenditure or social cost of wetlands restoration in the MAV.

Again considering the values reported in Table 8, it would only take two years for the social benefits of wetlands restoration (~$1800/ha/yr) to surpass the costs incurred by the government in paying for the WRP. Furthermore, the estimated social benefits represent a lower bound on the total ecosystem value since several ecosystem services are not accounted for in the analysis. The ecosystem service value return on public investment appears to be very attractive in the case of the WRP.

BENEFIT AGGREGATION FOR MAV

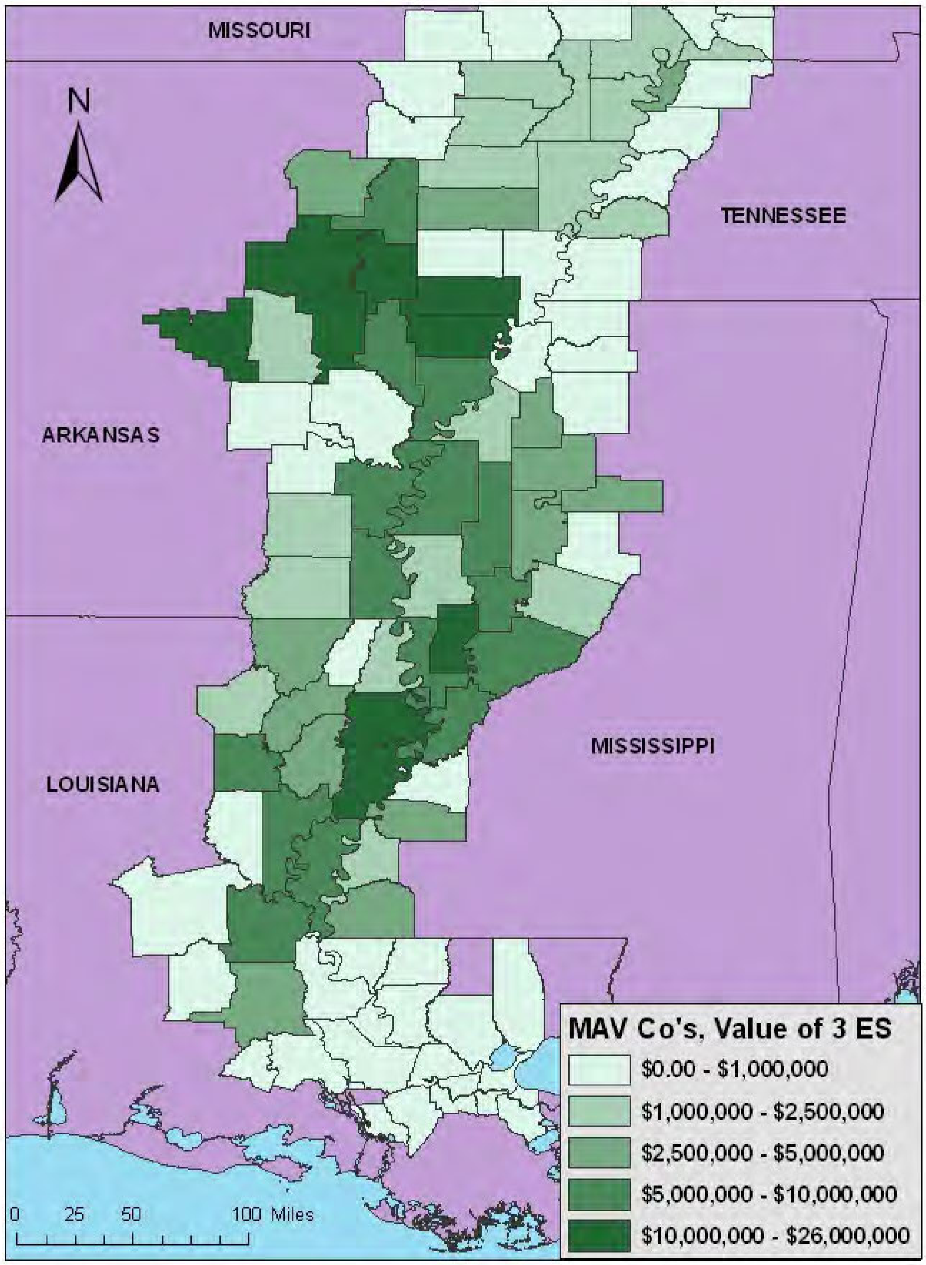
The measurement of aggregate benefits resulting from a program can be useful to policymakers by providing an estimate of the magnitude of program impacts. Using the per-hectare values for the three focal ecosystem services, we can scale them up to generate aggregate values for the study area, the three major river basins of the MAV. Examining the benefits associated with the land currently enrolled in WRP there, we observe that there are 226,522 hectares in WRP easements in the 104 counties in the MAV (as of 2005). With the assumption that the services are provided equally by each WRP hectare, we apply their social welfare values, which are $213.40 per hectare for the GHG mitigation value (using $15/t$CO_2$e), $1268.12 for the nitrogen mitigation, and $15.93 for waterfowl recreation. Multiplying these values by the number of WRP hectares located in each county, we calculate county-level estimates of the bundled values of the three services and then sum those to arrive at an aggregate value at the spatial scale of the MAV (see Table 9).

Table 9. Annual GHG mitigation, nitrogen mitigation, and waterfowl recreation values (2008 US$) for WRP land combined at the MAV level.

	Extent (ha)	GHG mitigation	N mitigation	Waterfowl recreation	Aggregate value
WRP per hectare		$213	$1,268	$16	$1,497
All WRP land	226,522	$48,339,795	$287,257,079	$3,608,495	$339,205,369

The differential distributions of bundled ecosystem service values across the study area counties is reflected in Figure 8, a map displaying the value of the three ecosystem services on WRP land for each of the counties. Higher values are represented by progressively darker shades of green coloring the counties. Annual MAV-level benefits are approximately $339 million, although 25 of the 104 counties supply almost 75% of the value.

Figure 8. Counties of the Mississippi Alluvial Valley (MAV) by annual aggregate social value of the three bundled ecosystem services generated on restored wetlands on WRP land.



CONCLUSIONS

As public goods, ecosystem services are underprovided because they are undervalued in the marketplace. Thus far, government programs such as WRP and CRP have sought to increase the flow of these services, and they have attained a certain level of success, as has been demonstrated by this analysis. However, with increasing public recognition of the importance of healthy ecosystems to human welfare also comes the potential for new economic opportunities in the form of private ecosystem markets. Policymakers and business entrepreneurs need good information on the economic value of ecosystem services to guide their programs and market development efforts. This paper addresses that need.

The Mississippi Alluvial Valley is a particularly rich ecosystem that has undergone massive change in the last 100 years. It has been a recent target of restoration efforts through WRP, CRP, and other programs. To examine ecosystem service values from WRP restoration in this region, we combined field data collection with secondary data collection and then linked these data with process models to calibrate expected change in those values. Unlike many other ecosystem service studies that have used top-down, landscape-level approaches, we implemented a bottom-up integration of ecosystem service function measurements, environmental modeling, and economic valuation.

Focusing on three services—GHG mitigation, nitrogen mitigation, and waterfowl habitat—we estimated a lower bound for the economic value to society of restoring wetlands in the MAV. With advances in methodologies and markets, that value will likely grow as currently unmonetized services, such as floodwater storage, gain their own price tags. Considering the lower bound estimate, this study's findings suggest that restoring wetlands in MAV has a total economic value to society well above the alternative use in agriculture. The largest benefits are found to flow from nitrogen mitigation, followed by GHG mitigation. Nevertheless, absent expanded public programs or new ecosystem service markets to deliver payments, landowners are being economically rational by keeping most of this land in agriculture, which currently has a higher market return. As a result, some mix of expanded payments from the public or private sector would appear to be warranted to incentivize continued wetlands restoration at a net benefit to society.

From the taxpayer perspective, the social benefits easily outstrip the social costs of restoring wetlands via WRP, as the public investment pays for itself in enhanced ecosystem services in only two years. Again, these benefit estimates do not include other services that do not presently have a clear monetary value, but may in the future. Given the considerable "surplus" in conservation effects generated by WRP payments, there could be substantial opportunity for mitigation markets in the region to supplement, or possibly even replace, conservation program payments.

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Ecosystem Service Analysis of the Yazoo Pumps Project

For submission to the EPA

in Support of a Veto on the proposed Yazoo Pumps Project

May 5, 2008

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Acknowledgments

Special thanks to Isabel de la Torre, Maya Kocian and Erinna McCarthy for support and assistance with this report.

Executive Summary

Earth Economics strongly supports an EPA veto of the Yazoo Pumps project. Army Corps analysis of the project is deeply flawed omitting entirely the loss of critical ecosystem functions and services. The Yazoo Pumps project will have a vast and long term impact on wetlands in the Yazoo Backwater area.

There is a great deal of uncertainty and debate concerning the actual area of wetlands to be impacted by this project. This analysis takes the most conservative Army Corps figures for complete draining of 26,300 acres of wetlands, 18,000 of which are forested wetlands, the rest area assumed to be herbaceous or shrub wetlands. With an additional 40,700 acres of wetlands being negatively impacted.

This report supports the consensus in the economic discipline that natural systems, including wetlands, are economic assets. They provide highly valuable economic goods and services including flood protection, drinking water provision, fisheries production, recreation and habitat among others. For some of these goods and services, dollar values can be established.

Using a benefit transfer methodology and the Army Corps' estimate of the wetlands impacted at 65,000 acres, Earth Economics estimated the range in value for 7 of 23 identified economically valuable ecosystem services between $22-90 million/year in this area with a net present value between $462 million and $1.9 billion dollars at a 5% discount rate.

This net present value is analogous to a capital asset value for the 65,000 acres impacted. These figures are large because the value of services the public receives as public goods and services is large. The public receives benefits from these vital natural assets, yet pays very little or nothing for their "capital construction" costs and maintenance. This means that these natural assets are more valuable because they do not require the costs associated with built capital.

By using the lowest and highest values in the academic peer reviewed literature this analysis compensates for inherent uncertainty. Though these figures are certainly underestimates of the true value of ecosystem services provided by this area, they are robust and far better estimates than the assumption of zero value, which the Army Corps has made in their economic analysis.

Ecosystems and particularly forested wetlands are economic assets providing a suite of 23 highly valuable ecosystem goods and services. Although rendered for free, these ecological goods and services are valuable. The Yazoo Backwater Area provides flood protection, natural storm mitigation, nutrient flows, biodiversity, wildlife habitat, fisheries, aesthetic value, and other public goods and services. Many of these services traverse large areas and a far larger population of US citizens than this project would benefit. For example, over 3 million people living downstream will be negatively impacted by the loss of water quality, natural water conveyance and backwater functions of the Yazoo area. Millions of Americans that enjoy the migratory wildlife passing through Yazoo along the Mississippi flyway will experience a reduction in wildlife viewing, harvest and enjoyment. Most of these highly valuable services are public services which are non-excludable, benefiting everyone. The Army Corps of Engineers has failed to account for any of these important values in their analysis. The Corps has basically counted the ecological services of this area as having zero value. This project is painfully similar to the Army Corps' failure to include the storm protection benefits of wetlands at the mouth of the Mississippi River.

Large infrastructure decisions which involve water or other ecosystem goods and services should be informed by the best available understanding and analysis of the relationships between watershed ecosystem health and the provision and value of watershed goods (like water) and services (including wildlife habitat, flood protection, water filtration, waste assimilation and other services).

Although rendered for free in terms of market price, these services have high economic value. The majority of economic value, or special benefits, provided by ecosystem services are produced as economically non-excludable services for landowners as well as members of the general public. This report estimates the economic value of forested wetlands in the Yazoo Backwater area. This case is made using ecosystem service valuation, the best available scientific method for quantitative analysis of the relationships between ecosystem health and economic benefit.

Earth Economics utilized the best economic methods currently available for estimating the value of ecological goods and services produced by Yazoo Backwater Area. We adopted a 65,000 acre figure using a benefit transfer methodology. This methodology is based on peer reviewed academic journal articles in order to estimate the high and low dollar value range of a list of 23 ecosystem services produced within the acreage of each vegetation type. These values were then summed for an initial rough-cut total valuation of ecosystem goods and services provided annually by each area. These values were then modified according to the particular area of Yazoo Backwater Area being examined. To get a sense of the asset value, the present value (PV) was then calculated to demonstrate the annual flow of ecosystem benefits.

Introduction

This economic analysis aims to demonstrate costs not included in the Army Corps analysis with a valuation of the ecological goods and services generated within Yazoo Backwater Area .

This study uses a natural capital approach to policy and asset management, identifying and estimating the value of those goods and services produced by natural capital. These ecosystem service valuations build off recent studies conducted by David Batker and others at Earth Economics in support of salmon habitat restoration for the Water Resource Inventory Area 9 (WRIA 9) Steering Committee and the King County Department of Natural Resources (Batker et al, 2005) and also for the Seattle Public Utilities Tolt River Watershed Asset Management Plan (Batker, 2005) as well as a General Technical Report for the United States Department of Agriculture, Forest Service Pacific Northwest Research Station (Batker, 2006).

While ecosystem and resource management decisions typically focus on "built capital" and financial assets, they are critically dependent on "natural capital" for provision of water, drainage, electricity, flood protection, and other benefits. Watersheds and other ecosystems are capable of providing a full range of 23 identified categories of ecological goods and services. An understanding of the relationships between watershed ecosystem health and the provision and value of these goods and services can better inform public investment decisions.

The next section describes the key concepts for including natural capital.

1. <u>Key Concepts</u>

The scientific field of Economics has advanced significantly in recent years in ways that improve our ability to quantify the value and impacts of resource management strategies. A great deal of research since 1985 has focused on developing and refining methods, tools, and techniques for measuring the value produced by natural systems. These include new concepts such as "natural capital" and new techniques including ecosystem service valuation.

1.1. Natural Capital and Asset Management

Ecosystems and natural resources, or natural capital, have previously been viewed as virtually limitless compared to human-built capital. In the past, they were considered as "free" and therefore of no value. Given the increasing scarcity of healthy ecosystems, the valuation of natural capital helps decision makers identify costs and benefits, evaluate alternatives, and make effective and efficient management decisions. Excluding natural capital in asset management can result in significant losses, increased costs, and decreases in efficiency and community benefit.

1.1.1. Understanding Natural Capital

Natural capital is comprised of geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continual return of valuable benefits (Daly and Farley, 2004). It contributes to our economy and quality of life in many ways that are not currently included in policy considerations. This includes provision of water, natural water filtration, energy production, flood control, recreation, natural storm water management, biodiversity, and education. Consideration of the Yazoo Backwater Area and other ecosystems as natural capital helps provide a more complete view of ecosystem health and the production of valuable benefits.

1.1.2. Economics of Natural Capital

Healthy ecosystems are self-maintaining, they have the potential to provide an ongoing output of valuable goods and services in perpetuity and to appreciate in value over time. In contrast, built structures and other man-made capital have a tendency to depreciate in value over time and require significant financial inputs for operations and maintenance. Without incorporating the ecological and economic value of natural capital affected by the Yazoo Pumps project the proposal cannot provide a clear understanding of the full costs and benefits. This is the case, thus the Yazoo Pumps project economic analysis provided by the Army Corps is catastrophically flawed. Investment of public funds in infrastructure projects must include the full impact on natural capital.

Public and private landowners have a unique opportunity to understand the full economic importance of ecosystems in services. Public agencies like the Department of Interior have put substantial investments into acquiring and improving natural assets in the Yazoo Backwater area. This project threatens to unravel these important public investments.

Natural systems are both ecological and economic assets. The provision and filtration of water is a good example. The city of New York accepted in 1997 the importance of ecosystem service valuation when considering long term supply options for a city that demanded a daily supply of more than one billion gallons of water. Facing degraded drinking water quality, New York City weighed the options of building a water filtration plant costing over $7 billion or of investing $1.5 billion to restore the health of the watershed and allow natural processes to filter the water and meet drinking water standards. The City decided to invest in watershed restoration that had a far higher rate of return, a less costly and less risky method for meeting standards.

Ecosystems in the Yazoo Backwater Area can be managed in a way that optimizes the aggregate value of goods and services with potential to benefit current and future generations. This is only possible if large infrastructure proposals thoroughly include analysis of the ecological and economic benefits of affected areas.

1.2. Ecosystems and Value Production

Ecosystems comprise of individual structural components (trees, forests, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, etc.) that generate ecological goods and services (salmon, timber, flood protection, recreation, etc.). **Figure 1** below summarizes these relationships in a simplified diagram. Ecosystem infrastructure has particular physical components within given boundaries of the ecosystem. The infrastructure itself is dynamic, as biotic structures migrate and abiotic components flow through the watershed, often via air or water. These functions vary widely in spatial boundaries (oxygen migrates globally, spawning habitat is locally confined). Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production). These structures, processes, and functions combine to produce economically valuable goods and services.

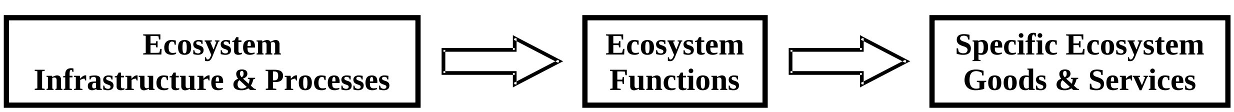

Figure 1. Relationship of Ecosystems to the Goods and Services Produced

Ecosystem service valuation assigns a dollar value on goods and services provided by a given ecosystem. This allows for proposed management policies to be considered in terms of their ability to improve ecological processes that produce the full diversity of valuable ecosystem goods and services. Often these ecosystem services are lost or gained as a full basket. As 2,000 square miles of wetlands in the Mississippi Delta have been lost, largely due to the Army Corps of Engineers levying of the Mississippi River, hurricane protection, water quality, wildlife habitat, recreation opportunities have all been lost. The retreat of the coastline now threatens the very inhabitability of the coast and major cities such as New Orleans. Restoring these ecological processes within a natural range of variability maintains structure and the ecological goods and services that follow. Further study will show the value of ecological goods and services contributed by all restoration sites, thereby showing the low estimate of the cumulative value brought in by these restorations sites to present and future generations.

1.2.1. Ecosystem Goods

Ecosystems provide a variety of useful goods like water, timber, and fish. Most goods are excludable; if one individual owns or uses a particular good, that individual can exclude others from owning or using the same, i.e., if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets. The production of goods can be measured by the physical quantity produced by an ecosystem over time, such as, the volume of water production per second, the board feet of timber production in a 40-year rotation, or the weight of fish harvested each year. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. This production creates a flow of ecosystem goods over time.

1.2.2. Ecosystem Services

Ecological services are defined as “the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life” (Daily et al., 1997). Ecosystems provide a variety of services that individuals and communities use and rely upon, not only for their quality of life, but also for economic production (Daily, 1997; Costanza et al., 1997). Ecosystem services are measurable benefits that people receive from ecosystems. Ecosystems produce goods and services as a result of ecosystem process, function, and structure.

The stream of services provided by an ecosystem is referred to as a “service flux.” A flow of goods can be measured in quantitative productivity over time while a service flux is generally more difficult to measure and value. Ecosystem services are in many cases non-excludable services. A healthy watershed provides aesthetic value to anyone who looks at it as well as the benefit of flood protection to all people downstream. As a result of this non-excludability, most ecosystem services are not sold in markets. Table 1 shows a list of ecosystem services.

Table 1. Examples of Ecosystem Services (from Dailly et. al., 1997)

Purification of the air and water
Mitigation of floods and droughts
Recreation
Detoxification and decomposition of wastes
Generation and renewal of soil and soil fertility
Pollination of crops and natural vegetation
Control of the vast majority of potential agricultural pests
Dispersal of seeds and translocation of nutrients
Maintenance of biodiversity
Protection from the sun’s harmful ultraviolet rays
Partial stabilization of climate
Moderation of temperature extremes and the force of wind and waves
Support of diverse human cultures

Provision of aesthetic beauty

1.2.3. The Value of Ecosystem Services Relative to Ecosystem Goods

While the value of a service flux may be more difficult to measure, its value may, in many cases, significantly exceed the value of the flow of goods. A study of Philippine mangroves showed that the services of storm protection and nursery functions (85% of commercial fish species are dependent on the mangroves for a period of time within their lifecycle) produced several times the value of shrimp aquaculture operations that replaced the mangrove ecosystems (Boumans et al., 2004).

1.2.4. Process, Function, Structure and Value Production

The quality, quantity, reliability, and combination of goods and services provided by the ecosystems within a watershed depend highly on the structure and health of the ecosystems within the watershed. Structure refers to a specific arrangement of ecosystem components. The importance of ecosystem structure can be understood by using the car as a metaphor. The steel, glass, plastic, and gasoline that comprise a car must retain a very particular structure to provide transportation service. Having a pile of the same constituent materials but absent a car's structure, this "car" cannot provide transportation service. Salmon require certain processes, structures, and conditions. Ecological service production is more dependent on structure than the flows of goods. A single species timber plantation may yield a flow of goods (timber) but it cannot provide the same service fluxes (biodiversity, recreation, and flood protection) as an intact natural forest.

1.2.5. Integrated Ecosystems

A heart or lungs cannot function outside the body. Neither can the human body cannot function without a heart and lungs. Good health requires organs to work as part of a coordinated system. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts. Each of the physical and biological components of the watershed, if they existed separately, would not be capable of generating the same goods and services provided by the processes and functions of an intact watershed system (EPA, 2004). Ecosystem services are systems of enormous complexity. Individual services influence and interact with each other, often in nonlinear ways (Limburg et al., 2002).

1.2.6. Value Production "In Perpetuity"

Healthy intact ecosystems are self-organizing (require no maintenance) and do not depreciate. They can provide valuable ecological goods and services on an ongoing basis "in perpetuity" and without cost to humans. A forest provides water control, flood protection, aesthetic and recreational values, slope stability, biodiversity and other services without maintenance costs. This differs from human-produced goods and services (cars, houses, energy, telecommunications, etc.) that require maintenance expenditures, dissipate, may depreciate, and usually end up discarded, requiring further energy inputs for disposal or recycling. Destruction of ecosystem functions disrupts an ongoing flux of valuable ecological services. Filling flood plains increases flooding. When an ecosystem's free natural flood prevention functions are destroyed, flood damage will exact continuing costs on individuals and communities who must either suffer flood damage or pay for engineering structures and storm water infrastructure to compensate for the loss. Without healthy ecosystems, taxpayers, businesses and governments incur damage or costs to repair or replace these ecosystem services. When ecological services are restored, the reverse dynamic can occur.

In the case of the Yazoo Pump project, natural capital, and self-maintaining natural water conveyance is being replaced with a highly capital intensive system that will require on-going maintenance and will eventually have to be rebuilt, requiring capital asset investments in the future. This locks taxpayers into an ongoing expense and threat to wildlife which is simply unnecessary.

2. Ecosystems Services Valuation Analysis Overview

The methodology for valuing ecosystem services involves the identification and categorization of ecological services, identification of the area and vegetation type of the affected lands and peer-reviewed studies of market and non-market values using direct use and indirect use valuation methods. Economic valuation data from peer reviewed academic journal articles were aggregated using a value transfer methodology to estimate a high and low dollar value range for a list of 23 ecosystem services (water purification, flood control, climate regulation, etc.). Economic modeling was used to integrate data on the health, age, and species diversity of the ecosystems on the study site. Initial analysis resulted in a rough-cut total valuation of ecosystem goods and services provided annually by each area. Long-term economic value was also calculated by calculating a 5% present value of the annual flow of ecosystem benefits. This is analogous to a natural capital asset value which can be used within an Army Corps economic framework to include the cost of lost natural assets. The next sections discuss the analysis process in more detail.

2.1. Ecosystem Service Categorization

De Groot et al. (2002) categorized 23 ecosystem processes and functions of ecosystem services (see Table S) based on a review and synthesis of the valuation literature on ecological services. These are grouped into four function categories: 1) regulation, 2) habitat, 3) production, and 4) information. Regulation and habitat functions are considered essential functions that are necessary before production and information functions can be active (De Groot et al., 2002). Table 2 provides a list of 23 ecosystem services, their functions, infrastructure and processes with examples.

Table 2. Ecosystem Functions, Processes, and Services (from De Groot et. al., 2002)

Functions		Infrastructure and Processes	Examples of Good and Service
Regulation Functions		*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles	Provides clean breathable air, disease prevention, and a habitable planet
2	Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favorable climate, promotes human health, crop productivity, recreation, and other services
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	Prevents and mitigates natural hazards and natural events generally associated with storms and other severe weather
4	Water regulation	Role of landcover in regulating runoff and river discharge	Provides natural irrigation, drainage, channel flow regulation, and navigable transportation
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers and snowpack)	Provision of water for consumptive use; includes both quality and quantity
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	Maintains arable land and prevents damage from erosion, and promotes agricultural productivity
7	Soil formation	Weathering of rock, accumulation of organic matter	Promotes agricultural productivity, and the integrity of natural ecosystems

8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients	Promotes health and productive soils, and gas, climate, and water regulations
9	Waste treatment	Role of vegetation and biota in the removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification, Filtering of dust particles through canopy services
10	Pollination	Role of biota in the movement of floral gametes	Pollination of wild plant species and harvested crops
11	Biological control	Population control through trophic-dynamic relations	Provides pest and disease control, reduces crop damage
Habitat Functions		*Providing habitat (suitable living space) for wild plant and animal species*	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity (thus the basis for most other functions)
13	Nursery function	Suitable reproduction habitat	Maintenance of commercially harvested species
Production Functions		*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	Hunting, gathering (fish, game, fruits, etc.) small scale subsistence farming, and aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing, fuel and energy, fodder and fertilizer
16	Genetic resources	Genetic material and evolution in wild plants and animals	Improve crop resistance to pathogens and pests
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs, pharmaceuticals, chemical models, tools, test and essay organisms
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs
Information Functions		*Providing opportunities for cognitive development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc., use of nature for scientific research

2.2. Value Transfer in Economic Valuation

The methodology of value transfer was used to conduct this economic valuation. Conducting original studies for every ecological service on every site for every vegetation type is cost and time prohibitive; researchers developed a technique called benefit or value transfer which is a widely accepted economic methodology wherein the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in other comparable locations.

This valuation is akin to a house appraisal where an appraiser considers the valuations (sales) of houses in different locations, the similar and different attributes, and specific aspects of the house and property being appraised. The number of bedrooms, condition of the roof, unfinished basement, and view are additive values for estimating the full value of the house. These additive values provide different services and contribute to the total value of a house.

The Gund Institute for Ecological Economics (GIEE), the leading national ecological economics institution, has compiled a database of published, peer-reviewed ecological service valuation studies. The database provides value transfer estimates based on land cover types and is updated as new literature becomes available. In addition, Earth Economics has recently completed a review of valuation studies in the Mississippi Delta including values for hardwood wetland forests very similar to those found in the Yazoo Backwater area.

The value of the ecosystem services described above is additive. An acre of forestland provides water regulation and filtration services and aesthetic, flood protection, and refugium benefits. One study may establish the value per acre of a watershed in water filtration for a drinking water supply. Another study may examine the value per acre of refugium for wildlife. To determine the full per acre value provided by a vegetation type, ecosystem service values are summed up and multiplied by the acreage.

The valuation techniques utilized to derive the values in the database were developed primarily within environmental and natural resource economics. As Table 3 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing, and contingent valuation.

- ***Direct use value*** involves interaction with the ecosystem itself rather than via the services it provides. It may be consumptive use such as the harvesting of trees or fish, or it may be non-consumptive such as hiking, bird watching, or educational activities.

- ***Indirect use value*** is derived from services provided by the ecosystem when direct values are not available. This may include the removal of nutrients, providing cleaner water downstream (water filtration), or the prevention of downstream flooding. Studies may derive values from associated market prices such as property values or travel costs. Values can also be derived from substitute costs like the cost of building a water filtration plant when natural ecosystem filtration services are disturbed and fail. Contingent valuation is an additional method that entails asking individuals or groups what they are willing to pay for a good or service.

Table 3. Methods for Primary Research in Ecosystem Service Valuation

Direct Use Values	
Market Price	Prices set in the marketplace appropriately reflect the value to the "marginal buyer." The price of a good tells us how much society would gain (or lose) if a little more (or less) of the good were made available.
Indirect Use Values	
Avoided Cost	Value of costs avoided by ecosystem services that would have been incurred in the absence of those services, e.g., flood control provided by barrier islands avoids property damages along the coast.
Replacement Cost	Cost of replacing ecosystem services with man-made systems, as when nutrient cycling waste treatment are replaced with costly treatment systems.
Factor Income	The enhancement of income by ecosystem service provision, e.g., water quality improvements increase commercial fisheries catch and incomes of fishermen.
Travel Cost	Cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service, e.g., recreation areas attract tourists whose value placed on that area must be at least what they were willing to pay to travel to it.
Hedonic Pricing	The reflection of service demand in the prices people will pay for associated goods, e.g., housing prices along the coastline tend to exceed the prices of inland homes.
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives, e.g., people would be willing to pay for increased preservation of beaches and shoreline.
Group Valuation	Discourse-based contingent valuation which is arrived at by bringing together a group of stakeholders to discuss values to depict society's willingness to pay.

2.2.1. Methodology for Comparison of Management Scenarios

Were time and resources permitting, the various project options could be compared with future scenarios. In such cases, this section would include individual ecosystem service valuation analysis for present state and/or management options with cost estimates for management changes in order to integrate valuation into full cost-benefit analysis. Time and resources did not allow this analysis to be conducted at this time.

2.2.2. Present Value Calculation and Discounting

The assessment and management of ecosystem service flows earned over generations is a difficult challenge. The stream of benefits can reflect current costs of capital or other financial opportunity costs but due to social discount rates, we tend to undervalue benefits that will be received in the future or by future generations. The discount rate assumes that the benefits we harvest in the present are worth more than the benefits that are provided for future generations, a view that those in the future may not share.

Discount rates that are used in public land management project appraisal can be based on a variety of rate sources including the prime rate of interest, the market rate of interest, and inferred social discount rate. Based on rates used for project appraisal by the Army Corps of Engineers, this report provides net present value (NPV) calculations with the three discount rates of 3.5%, 5%, and 7%. Since it is common for reduced discount rates to be applied to forestry projects, this also includes a zero discount rate analysis of long-term flows of ecosystem services.

The tendency of discounting for present value maximization encourage decision makers to select projects that pull short-term benefits into the present and push costs into the discounted future. Over the long-term, this increases the risk of amplifying intergenerational inequities. In economic terms, potentially unsustainable management practices will tend to liquidate renewable resources for short-term gain at much greater long-term expense or loss of value.

Economists solve this dilemma by defining a sustainable scale for the use of ecosystem services, one where basic ecosystem services within a watershed are kept intact. This ensures ecological sustainability where future generations are not left with an unviable set of ecological systems. The vast majority of value provided by a healthy ecosystem is held in the indefinite future. Today, we reap a thin annual slice of benefits from this continuous stream of the 23 categories of ecosystem goods and services.

Ecosystems are assets, a form of wealth. Many ecosystem services are necessary for our survival: oxygen production, waste decomposition, and storm protection. This asset of natural capital provides a stream of benefits that current and future generations require. This is unlike non-renewable resources, such as burning gasoline, or human-built capital like a new car. They burn up, are used up, or depreciate to eventually become waste, requiring further energy inputs for recycling. The primary benefits of non-renewable and human-built capital are held closer to the present. This is an important distinction between natural and human-built capital. In addition, value is not fixed in time; the values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al. 2002).

Healthy ecosystems are self-organizing, often not requiring maintenance. They do not depreciate, can provide goods and services potentially in perpetuity, and hold vast amounts of value in the distant future. As a result, it is important to illustrate the value of these ecosystem services by considering their value without discounting.

A calculation of value produced by Yazoo Backwater Area using a zero discount rate was used to provide a glimpse of how the people of [#Stakeholder, region] would see the stream of future ecosystem service benefits. Ecosystem services have, in fact, increased in value at an accelerating rate as they become increasingly scarce. This is expected to continue with current development projections in the area. Thus, the true value of these services may be much larger.

Critical Natural Capital

TheYazoo Backwater Area currently houses critical ecosystem processes and ecological services. These services cannot be transferred. A marginal increase in agricultural production, the primary benefit of this project can be provided in many areas in the State of Mississippi or within the United States. However, the unique ecological services, habitat, value for migrating wildlife, water quality and other benefits of the Yazoo wetlands cannot be marginally moved elsewhere in Mississippi or the US

The benefits of the Yazoo Backwater Area redound to the long-term interest of the public both local and national. The Yazoo Pumps project would result in ecological process changes that would degrade vast areas of wetlands and the ecological services they provide. This would likely result in a substantial loss of benefits and potentially substantial costs incurred by the public.

Study Limitations

This study provides a best-possible first estimate of the economic value of the ecological goods and services generated within Yazoo Backwater Area. The study, is based primarily on value transfer and not on original research of each ecosystem service within Yazoo Backwater Area, should be regarded as the best first estimate with the potential for improved accuracy from further research.

While a number of study limitations should be kept in mind when considering the results, these limitations do not detract from the fact that ecosystem services provide high value. EPA is better informed with fact-based estimates rather than an implicit assumption of zero value for the following reasons:

1. ***Limited ecosystem service studies.*** Although the field of ecosystem service valuation has expanded rapidly, regionally relevant studies are still extremely limited. The value of some ecosystem services has not been estimated. For example, the value to people of ecosystem processes the full wildlife benefits of Mississippi hardwood wetland forests have never been estimated. Where ecosystem services of value are identified and valuations have not been conducted, zero value is the default estimate. This contributes to values for both the low and high valuations that are underestimates. For this reason, the values calculated here should be considered underestimates.

2. ***Uncertainty and service identification.*** Some ecological services may not yet be identified. The dollar estimates of the value produced by natural systems are inherently underestimates. For example, while we may be able to place a dollar value on the water filtration services provided by a forest, we cannot fully capture the aesthetic pleasure that people gain from looking at the forest, nor every aspect of the forest's role in supporting the intricate web of life. Thus, most ecological service valuations serve as base markers somewhere below the minimum value of the true social, ecological, and economic value of an ecological service.

3. ***Lack of appropriate valuation studies.*** Medicinal, historic and spiritual values were identified within the area affected by the Yazoo Pump project, but eliminated from the study because existing studies were inappropriate for this area. However, assuming that Yazoo Backwater Area produces no value in these categories is incorrect and reduces its true value. Taxol, a breast cancer drug was discovered from the Northwest yew tree that occurs in all western Washington watersheds. No methodology on how to distribute this value to the ecosystem that produced it on a per acre basis has yet been developed. Historical values are site specific and resources were insufficient for a specific study of Yazoo Backwater Area. Similarly, there is no accepted method for monetizing cultural or spiritual value.

4. ***Static analysis.*** The values of goods and services, natural capital or otherwise, are dynamic. The current analysis provides a "snapshot" of value in Yazoo Backwater Area and for the project site. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al. 2002). This could give rise to a general tendency for value transfer based on studies performed over the past ten years to underestimate the value of ecological services produced by ecosystems today. Earth Economics is currently working under a National Science Foundation grant on a dynamic methodology for examining how changes in ecosystem processes change value over time.

5. ***GIS information.*** The GIS vegetation cover data used is coarse. For instance, it does not differentiate the quality of different wetlands. In other studies we have used the age of forest stands to provide an estimate of ecosystem health and services provided. A recently clear cut area will not yield the same flood protection, soil stabilization, or other services as an old growth forest. What is remarkable about the Yazoo area is the high quality of much of the habitat and the success of past restoration projects.

6. ***Process.*** Since this methodology is based on ecosystem services provided per acre of vegetation type, it does not pick up the full value of process changes. For example, the creation or occurrence of log-jams and barriers or restoring the natural processes of a watershed will have impacts beyond the project site because they are process changes. These are not captured in the geographical analysis of the site.

7. ***Irreversibility.*** Most economic modeling and analysis is a marginal analysis. Marginal analysis assumes a degree of reversibility that is not universally applicable to natural capital. Value changes

on the margins appear to be smooth, consistent, and continuous though this may not be the case in actual contexts.

8. ***Endangered species status.*** This report does not incorporate adequate analysis appropriate for consideration of endangered species as an element of critical natural capital. In particular, it overlooks any non-incremental impacts such as the potential for land management to contribute to a radical decline or even extinction in populations of endangered species.

3. Results of Ecosystem Service Valuation Analysis

3.1. Ecosystem Service Valuation of Yazoo Backwater Area

The ecological goods and services produced by each land cover type by Yazoo Backwater Area were estimated utilizing the methodological approach outlined in the previous section.

The total estimated value generated on the 65,000 acres of Yazoo Backwater Area in ecosystem services is estimated to be in the range of $22-90 million annually. The following sections and tables discuss this in more detail.

These estimates are based on the range of values for these land covers conducted outside Yazoo Backwater Area. As cursory estimates based on benefit transfer methodology they provide a ball-park range. A specific study or set of studies should be conducted to narrow the range in values.

3.1.1. Total Acreage of Yazoo Backwater Area by Landcover Class

Table 4 shows the acreages of GIS classification types that characterize Yazoo Backwater Area and were used for geo-spatial estimates for calculating ecosystem service valuation.

Table 4. Impacted Acreage (in hectares) of Yazoo Backwater Area by Landcover Class.

GIS Classification *	Acres
Wetland hardwood forests drained to non-jurisdictional	18,000
Wetlands, shrub and herbaceous drained to non-jurisdictional	8,300
Wetland hardwood forests negatively impacted	27,900
Wetlands, shrub and herbaceous negatively impacted	12,800
Total wetlands impacted	65,000

* The Army Corps provides few details on these impacted wetlands. For the 40,700 wetlands impacted, it is assumed that the same ratio of forested to non-forested wetlands is the same as the 26,300 acres where the Army Corps identifies the acres of wetland forest drained.

3.1.2. Valuation of Yazoo Backwater Area by Landcover Class

Tables 5 shows the estimates of ecological services produced by each GIS vegetation type within Yazoo Backwater Area. These estimates are all presented in $US. Because more valuation information was available for non-forested wetlands, they register a higher total per acre value. In fact, forested wetlands provide greater values for ecosystem services, however, valuation studies for hardwood bottom land Mississippi forests are not available for a range on aesthetic value or for wildlife habitat, refugium and nursery values. Because so many valuable ecosystem services have been identified but not valued, these dollar values should be considered underestimates of the true ranges in ecosystem service value. These values were derived from an ecosystem service database first developed by the University of Vermont Gund Institute for Ecological Economics later modified under a project for the State of New Jersey and further improved by Earth Economics. An excel spreadsheet linking each of the values in the table below to the corresponding published peer reviewed academic journal article is available upon request from Earth Economics.

Table 5. Valuation of Yazoo Backwater Area Wetland Forest Ecosystem.

Ecological Service	**Impacted Yazoo Wetland Forests**		**Impacted Yazoo Non-forested Wetlands**	
	Low	***High***	***Low***	***High***
Gas regulation	$21.11	$191.87	$29.43	$267.53
Climate regulation	$136.64	$136.64	$136.64	$136.64
Waste treatment	$3.13	$1,069.56	$3.13	$1,069.56
Water supply	$42.52	$113.39	$42.52	$113.39
Water regulation	$15.47	$15.47	$15.47	$15.47
Soil retention and formation	Not valued	Not Valued	Not valued	Not Valued
Fisheries	$25.80	$25.80	$53.37	$74.46
Nutrient regulation	Not valued	Not Valued	Not valued	Not Valued
Recreation	$134.44	$134.44	$134.44	$134.44
Pollination	Not valued	Not Valued	Not valued	Not Valued
Biological control	Not valued	Not Valued	Not valued	Not Valued
Refugium and Nursery function	Not valued	Not Valued	$185.51	$442.67
Food	Not valued	Not Valued	Not valued	Not Valued
Raw materials	Not valued	Not Valued	$4.26	$4.34
Genetic resources	Not valued	Not Valued	Not valued	Not Valued
Medical resources	Not valued	Not Valued	Not valued	Not Valued
Ornamental resources	Not valued	Not Valued	Not valued	Not Valued
Aesthetic information	Not valued	Not Valued	$68.09	$217.79
Cultural & artistic information	Not valued	Not Valued	Not valued	Not Valued
Spiritual & historic information	Not valued	Not Valued	Not valued	Not Valued
Science & education	Not valued	Not Valued	Not valued	Not Valued
Navigational services	Not valued	Not Valued	Not valued	Not Valued
Total	**$379.11**	**$1,687.17**	**$672.85**	**$2,476.29**

3.1.3. Present Value of the 65,000 acre portion of the Yazoo Backwater area

The present values of Yazoo Backwater Area ecosystem services are presented below in Table X. Under any calculation of PV, the ecosystem services provided by Yazoo Backwater Area are enormous and highly significant, ranging from a low of $462 million estimate at a 5% discount rate to $1.9 billion for the higher estimate boundary.

Table X. Present Value over 100 years with Various Discount Rates (in billion $US).

Discount Rate	Low Estimate	High Estimate
5 %	$462,000,000	$1,900,000,000

Conclusion

Earth Economics conducted this analysis by estimating the range of economic values for ecological goods and services produced annually by 65,000 acres of Yazoo Backwater Area. Of this, 18,000 acres are forested wetlands, 8,300 other wetlands with an additional 27,900 acres of forested wetlands and 12,800 acres of non-forest wetlands impaired. It was assumed that the impaired wetlands would produce half of the ecosystem services they previously provided.

Using USGS National Land Classification Data on vegetation types over these 65,000 acres, Earth Economics estimated the range of annual value provided by Yazoo Backwater Area ecosystem services $22-90 million. This results in a PV of $462 million to $1.3 billion at a 5% discount rate. A 3.5% discount rate, more commonly used for renewable, self-sustaining ecosystem services,

Most of the value provided by restoring healthy ecological processes in Yazoo Backwater Area will be garnered by future generations. The annual values calculated for Yazoo Backwater Area correspond to thin slices of the benefits that future generations will gain if Yazoo Backwater Area is maintained in an ecologically healthy condition. Unlike human-built capital, like cars and buildings, ecological capital appreciates and can be self-maintaining.

Both the high and low estimates of ecosystem services are likely underestimates of their true value. Most identified ecosystem services could not be valued. Other services that were valued are likely higher in Yazoo Backwater Area than in studied watersheds, for example, water purification and non-market valuations only captured partial values. The values of ecosystem services are rising rapidly due to increasing scarcity. In the case of recreation, the upper watershed is overvalued and lower watershed likely undervalued, with an ambiguous net result. The large ranges of value reflect the fact that benefit transfer methodology is an inexact science with significant uncertainty and variability. The ranges for these estimates will close with ongoing research. Nevertheless using inexact science for asset management is better than no science at all.

Recommendations

1. Eight ecosystem services, of 23 identified ecosystem services were valued for the 65,000 acres of wetlands potentially impacted by the Yazoo Pumps project. The range in value of these services is estimated to be between $22-90 million annually with a net present value range of $462 million to $1.9 billion.
2. The natural assets of the Yazoo Backwater Area are large and highly valuable. The value of these wetlands was not fully included in the US Army Corps of Engineers economic or environmental analysis.
3. **The EPA should veto the flawed Yazoo Pumps project.**
4. The Yazoo Backwater Area supplies sufficient ecosystem service benefits to justify significant restoration investments without the Yazoo Pumps project.
5. Because most of the benefits are held in the future, the estimate of value depends on how future value is weighted including what discount rate is used in this study we used a 5% discount rate, slightly higher than the Army Corps discount rate. The use of a lower discount rate would raise the net present value of the ecological services.
6. The EPA should partner with other organizations and agencies to increase the knowledge base on ecosystem services in the Yazoo area.
7. The public should be informed of the ecosystem services and their value, which Yazoo Backwater Area provides.

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Appendix A. Brief Descriptions of Some Ecosystem Services

A great number of studies examine the economic value of ecological services. These studies can be land use, vegetation type, or service based. A few services and valuation studies are discussed below.

Storm Protection and Flood Protection

Storm water management and flood protection provided by wetlands and other ecosystems are of vast value (Farber and Costanza 1987; Kenyon and Nevin 2001; Thibodeau and Ostro 1981). Wetlands between the Gulf States and the Gulf of Mexico, for example, provide buffer functions against hurricanes and tidal surges. As wetland buffers between the Gulf of Mexico and New Orleans have been lost, storm damage has increased dramatically. Existing wetlands prevent billions of dollars in storm damage from a single storm.

A Washington State wetlands study within WRIA 9 assessed the value of flood protection provided by wetlands in Renton, finding that Renton wetlands yielded flood protection benefits worth $41,300/acre to $48,200/acre (Leschine et al. 1997). Similarly, a draft study conducted in Portland, Oregon indicates that creation of a wetland to prevent flooding in a frequently flooded area of southeast Portland would prevent damage amounting to more than $500,000 per flood. This figure is based on actual damages to local homeowners in previous floods in the area (Rojas-Burke 2004).

Water Quality and Supply

Regulation of the quality and supply of water is perhaps the most recognized and studied ecosystem service. Studies have shown that the value of marginal improvements in water quality for specific areas range from $100 to over $1,000 per hectare (Bocksteal et al. 1988; Bouwes and Scheider 1979; Ribaudo and Epp 1984; d'Arge 1989; Desvousages et al. 1987; Cho 1990). Riparian forest buffers are estimated to reduce runoff nitrate levels by 84% and reduce sediment by more than 80% (Northeast Midwest Institute 2004).

Water purification services provided by natural ecosystems are far less expensive than water filtration and treatment facilities. New York City provided over $1.5 billion in watershed conservation measures to restore natural ecosystem filtration to meet water quality standards, rather than spend $8 billion (plus annual maintenance costs) to build a filtration plant (Krieger, 2001). Other jurisdictions have followed a similar pattern. To avoid the need to build a $200 million water filtration plant with additional maintenance and operating expenses, Portland, Oregon spends $920,000 annually to protect and restore the Bull Run watershed, maintaining the natural filtration of its drinking water supply (Krieger 2001). Annual operating costs of artificial water filtration vary. The estimated annual operating costs alone of water filtration facilities in Portland, Maine were $750,000, $3.2 million in Salem, Oregon, and $300 million in New York City (Krieger 2001). Healthy watershed ecosystems permanently provide filtration services, largely for free without capital, maintenance or operating costs.

Trees: Storm Water, Climate Regulation, and Atmospheric Pollutant Removal

Healthy ecosystems provide many bundles of services. Within these systems, trees provide a number of critical ecosystem services, and climate and air regulation have also been valued. One acre of forest can remove 40 tons of carbon from the air and produce 108 tons of oxygen annually (Northeast Midwest Institute 2004). Market values of carbon sequestration range from $10 – 100 per ton (Antle et al. 1999; McCarl et al. 2000; Haener and Adamowicz 2000) and $650 to $3,500 per hectare (Bishop and Landell-Mills 2002).

The level of service will differ based on the ecosystem structure (Bishop and Landell-Mills 2002). For example, a Douglas Fir forest plantation, planted ten years ago will not produce the same services as a natural old growth forest with a variety of tree sizes and species. Carbon sequestration in King County was estimated at about 56 million metric tons in 2000, and is predicted to average about 68 tons per acre in 2005, but the service varies significantly between types of growth (Turnblom et al. 2002).

The environmental purification and recovery of mobile nutrients – waste treatment services – provided by forests have been valued at $35 per acre (Loomis and Richardson 2000). Using land cover analysis, a 1998 report by American Forests related changes in the amount of vegetation and tree cover in the Puget Sound region to storm water management and air quality. The report placed an economic value on the ecology of the most urbanized parts of the Puget Sound watershed. The analysis valued the air quality by pollutants removed by the canopy cover at $166.5 million annually, and estimated storm water benefits amounting to $5.9 billion annually. Forestland is estimated to save about $21,000 per acre in storm water retention costs by capturing up to 50% of rainfall in the region (American Forests 1998).

Waste Treatment

Wetlands provide another important function for purifying water. A 1990 study found that the 11,000-acre Congaree Bottomland Hardwood Swamp in South Carolina removed the same amount of pollutants as the equivalent of a $5 million wastewater treatment plant (EPA 2003). A study in Georgia revealed that a 2,500-acre wetland saves taxpayers $1 million in water pollution abatement costs (EPA 2003).

Agricultural lands

One land use and policy based study (Ribaudo et al., 1989) estimated the following average benefit per acre of agricultural land under the US Conservation Reserve Program: soil productivity: $36; water quality: $79; air quality: $12; and wildlife: $86.

Pollination

Honeybees have been valued as natural pollinators for American cropland at $9 - $20 per hectare, and pollination services provided to US agriculture by all other pollinators are estimated at over $4 billion annually (Southwick and Southwick 1992).

Pest Control

Natural systems also provide pest control services. Estimates indicate that it would cost more than $7 per acre to replace the pest control services provided by birds in forests with chemical pesticides (Krieger 2001).

Recreational Value

Another valuable service that ecosystems provide is recreation. Uses such as fishing and hunting have been valued between $3 and $54 per trip (Adamowicz 1991). The fish and wildlife sector is a major economic force in Washington. Over $854 million was spent in 2002 on recreational fishing alone, while an additional $980 million was spent on wildlife viewing and $408 million on hunting (WDFW 2002). Commercial fishing added $140 million to the Washington economy in 2002 (WDFW 2002). Wildlife watching alone generates significantly more revenue for Washington's economy than the apple industry. It supports over 21,000 jobs in the state, more than any other Washington employer besides Boeing (WDFW 1997). Studies have found water quality for recreational purposes to be valued at $10 and $80 per year (Adamowicz 1991).

Aesthetic Value

Wetlands and other healthy ecosystems also provide aesthetic value, and the higher property prices around wetlands and forests reflect this phenomenon. A study in the Portland, Oregon area found that residential property values increased $436 for every 1,000 feet closer that a property was to a wetland (Mahan et al. 2000). Additional research has also assessed how other environmental amenities enhance property values (Crompton 2001; Anderson and Cordell 1988; Laverne and Winson-Geideman 2003; Dorfman et al. 1996).

Contingency Valuation, Restoration and Species Preservation

Contingency valuation establishes values for non-market goods by interviewing human stakeholders. Habitat valuations depend on the species that the habitat is for, and the use of those species for human demand. Many habitats are valued based on species used for consumption, such as oyster and other seafood production (Batie and Wilson 1978). Many other habitats are protected for valued megafauna (bear, elk, wolves) and protected endangered species. Studies of household values in the Pacific Northwest reflect strong preferences for protection of forests, fish and wildlife. In a study of estuarine function, residents of the Tillamook, Oregon area estimated the value of each additional acre of salmon habitat at approximately $5,000 (Gregory and Wellman 2001). Olsen and others (1991) found that households in the Pacific Northwest were willing to pay between $26-74 per year to double the size of the salmon and steelhead runs in the Columbia River (Quigley 1997). Another study found that Oregon households were willing to pay $2.50 to $7.00 per month to protect or restore salmon, a cumulative total of $2 million to $8.75 million dollars per month (ECONorthwest 1999). The mean annual value per household of river and fishery restoration on the Olympic Peninsula was $59 in Clallam County and $73 for the rest of Washington (Loomis 1996). Another study found Oregon households willing to pay $380 annually to increase preservation of old growth forests, $250 per year to increase endangered species protections, and $144 to increase protection for salmon habitat (Garber-Yonts et al. 2004).

Gaining Ground

Wetlands, Hurricanes and the Economy: The Value of Restoring the Mississippi River Delta

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Isabel de la Torre
Robert Costanza
Paula Swedeen
John Day
Roelof Boumans
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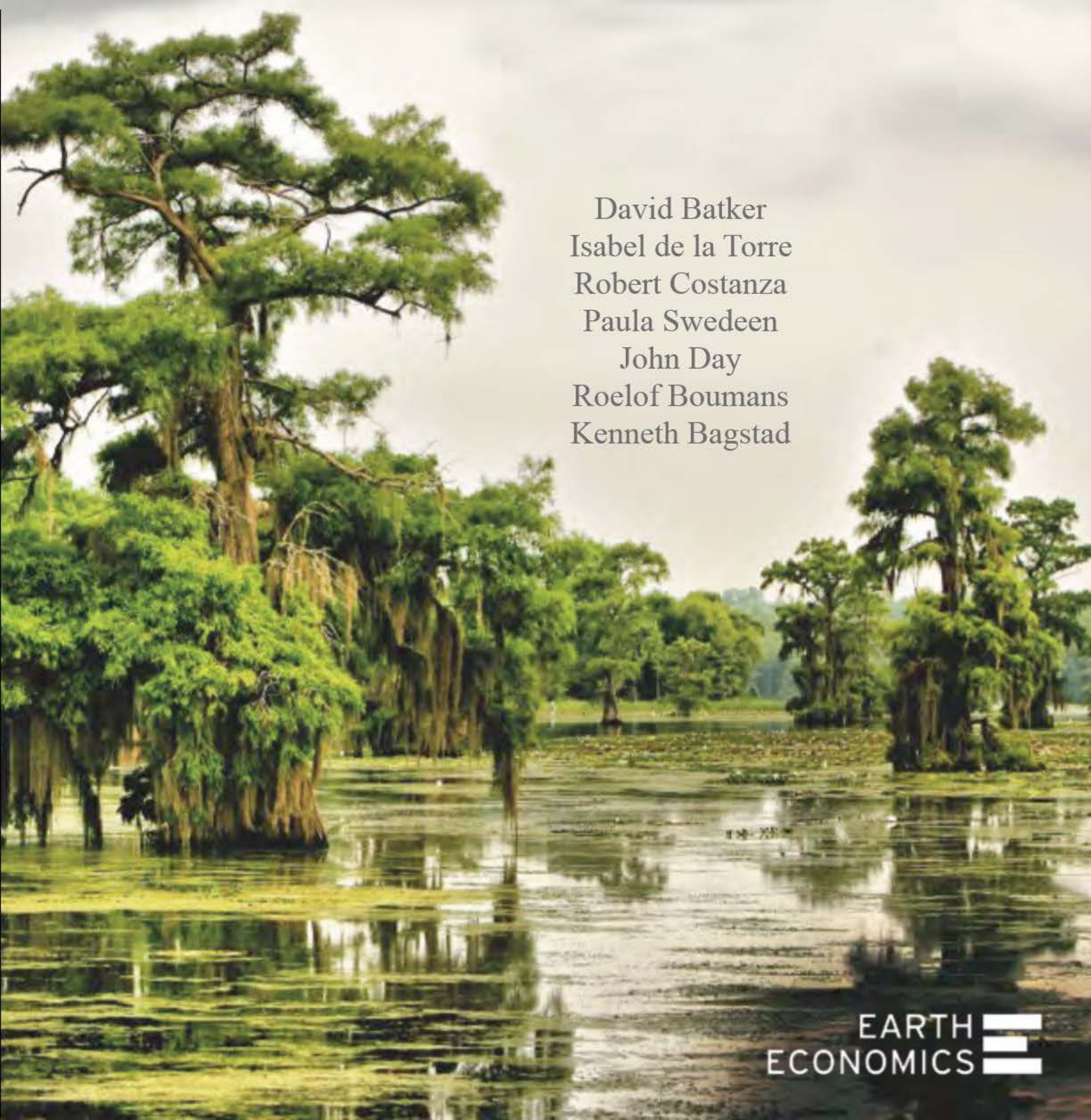

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June 2010

Acknowledgments

This report is a project of Earth Economics. The authors are responsible for the content of this report. Funding was provided by the Gaylord and Dorothy Donnelley Foundation, The McKnight Foundation, and a contribution from Norita Liebelt and Environmental Defense. We would like to thank the Louisiana State University School of the Coast and the Environment for hosting workshops and events that supported this report, the Gund Institute for Ecological Economics for their substantive contributions. We would like to thank the many people who contributed to portions of the report, reviewed drafts, and gave written and verbal comments. These include Louisiana Environmental Action Network Executive Director Mary Lee Orr, LSU Associate Vice Chancellor of Research and Economic Development Dr. Robert Twilley, Dr. Hassan Mashriqui of the LSU Hurricane Center, Dr. Paul Kemp of the National Audubon Society, Dr. Paul Templet former professor, Lake Pontchartrain Basin Foundation Coastal Sustainability Director John Lopez, Dean Wilson of the Atchafalaya Basinkeeper, Gulf Restoration Network Executive Director Cynthia Sarthou, Tulane Law School Professor Mark Davis, U.S. Geological Survey Ecologist Greg Steyer, John Barras of the Corps of Engineers, Juanita Russell of the US Army Corps of Engineers, Norwyn Johnson with the State of Louisiana, Edmond Russo of the U.S. Army Corps of Engineers, Coalition to Restore Coastal Louisiana Science Director Natalie Snider, Jim Tripp and Paul Harris of Natural Resources Defense Council, Alaina Owens of Coastal Louisiana Ecosystem Assessment and Restoration, Dr. Jenneke Visser of the University of Louisiana at Lafayette, Herman Daly of the University of Maryland, Annie Ducmanis of the Environmental Grantmakers Association, and Earth Economics staff Maya Kocian, Tedi Dickinson, Jim Pittman and Rowan Schmidt and Earth Economics board members Joshua Reyneveld, Joshua Farley, Ingrid Rasch, David Cosman and Jack Santa Barbara. Special thanks go to Micah Cote, Tighe Stuart, Justin Platts, Laurent Nickel, Jake Harris, Jenn McFadden, Hakme Lee, Colin Cronin, Darin Leedy, Patrick Miller and Zac Christin for their assistance in background research and fact checking.

Cover Photo by Paul Keith

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Roelof Boumans, an expert modeler, received his doctorate degree in 1994 as an ecosystem ecologist at the Department of Oceanography and Coastal Systems in Louisiana State University. His dissertation focused on the material fluxes through estuaries and involved processing large datasets through field book and datalogger recording. He developed insight into estuarine hydrology and published reports on ecological consequences to altering hydrology. At present, Dr. Boumans is the director of AFORDableFutures LLC a leader in the design and application of ecosystem based management tools to include the Multiscale Integrated Model of Ecosystem Services (MIMES).

Kenneth Bagstad, is a post-doctoral associate at the University of Vermont, where he received his PhD in 2009. Ken serves as the lead modeler for the NSF-funded Artificial Intelligence for Ecosystem Services (ARIES) project, which is building a series of web-accessible tools to map, assess, and value ecosystem services for environmental decision-making. Ken has also assisted in ecosystem service valuation studies for Louisiana, Washington State, Arizona, and Ontario, advised researchers working on Genuine Progress Indicator (GPI) studies for Michigan and Utah, and explored markets and ecosystem service-based funding mechanisms for ecological restoration in Illinois and Washington State. Ken also holds a B.A. from Ohio Wesleyan University and and an M.S. from Arizona State University.

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Executive Summary

> ***"As the great Mississippi River Delta disappears, so do the ecosystems, economies and people that it holds. The Mississippi River is the solution. It has the water, sediment and energy to rebuild land, defend against hurricanes and again provide habitat, safety, livelihood, and prosperity. We must look to the natural functioning of the delta to guide us in restoration."***
>
> ***John Day, 2007***

Economies need nature. Natural systems provide foundational economic goods and services including oxygen, water, land, food, climate stability, storm and flood protection, recreation, aesthetic value, raw materials, minerals, and energy. All "built capital" is made of natural capital, including cars, buildings and food. An economy also requires hurricane protection, a stable climate, waste assimilation and other natural services. No economy can function without nature's provision of economic goods and services. This is most apparent in North America's largest river delta.

The Mississippi River Delta ecosystems provide at least $12-47 billion in benefits to people every year. If this natural capital were treated as an economic asset, **the delta's minimum asset value would be $330 billion to $1.3 trillion** (3.5% discount rate)**.** This study is the most comprehensive measure of the economic value of Mississippi River Delta natural systems to date. Marine waters, wetlands, swamps, agricultural lands and forests provide natural goods and services. The goods and ecosystem services valued in this study include hurricane and flood protection, water supply, water quality, recreation and fisheries. The Mississippi River Delta is a vast natural asset, a basis for national employment and economic productivity. It was built by literally gaining ground: building land with sediment, fresh water and the energy of the Mississippi River.

Yet, this vast national economic asset is being squandered at tremendous cost. The Mississippi Delta lost over 1.2 million acres of land in the last 80 years. In some areas, the coastline has retreated by as much as 30 miles. The lower Mississippi River has been constricted by levees since the 1930s, resulting in billions of tons of valuable sediment and trillions of gallons of valuable freshwater being channeled into deep water off the edge of the continental shelf. The Mississippi's energy to move vast amounts of sediment and water could have built additional land and provided hurricane protection and other economic benefits at no significant cost.

Without the input of sediment and water, wetland systems collapse. Land is lost to the waters of the Gulf of Mexico causing tremendous economic and human cost. Wetlands provide vital protection against hurricanes. When land disappears, so do the economies, homes and communities that depend on it. Solving this problem requires an accounting of and investment in the economic assets of nature – natural capital – as an integral component of hurricane damage prevention and as a critical foundation for healthy communities and economies.

Is this national investment worthwhile during a period of financial crisis? The results of this report point to an unequivocal "yes." Seventy years ago, investments in roads yielded high economic returns because the U.S. was transitioning from a horse and wagon road system to a motorized system. Today, roads are neither scarce nor a barrier for economic recovery. Hurricane protection is scarce and hurricanes hamper national economic productivity; the disruption of oil and gas supplies alone cost U.S. citizens dearly. Today, a major investment in natural capital is required for economic development. An investment in restoring the Mississippi River Delta is both a local and national investment that realizes local and national economic benefits.

This report discusses the value of investing in the restoration of the Mississippi River Delta. Part I introduces a new view on the value of natural capital as a critical and large part of the economy. It also introduces ecosystem services and goods that directly benefit people but have historically been overlooked. Part II presents a valuation of ecosystem services in the Mississippi Delta, calculates their present value to assess the flow of value over time. Part III of this study examines the dramatic dynamic physical changes affecting the Mississippi River Delta and the profound economic implications for the region and our nation. Part IV examines three investment/restoration scenarios for the Mississippi Delta.

The first scenario involves doing nothing new: invest nothing in natural capital and keep building costly levees that are repeatedly damaged by storms while land continues to wash away. Practiced for 80 years, this option has proven to be very costly. It results in a retreating coastline in the Mississippi Delta, causing a retreat of people, communities, industry, built capital and the economy. This report estimates losses associated with this option at $41 billion. This does not include estimates of damage from another major hurricane, which is certain to happen. Considering that Katrina caused $200 billion in damage and that with further land loss future damage may greatly increase, this is a significant underestimate. The nation breathed a sigh of relief when Hurricane Gustav's glancing blow did not destroy New Orleans in 2008. Had the hurricane struck slightly to the east, the impact could have been more damaging. Hurricane Ike was perhaps more powerful than hurricane Katrina. The resulting devastation along the Texas coast demonstrated that the entire U.S. Gulf Coast and Eastern Seaboard are now vulnerable to hurricanes and storm surges of increasing power. The contribution of natural capital in protecting people and economic assets need to be considered throughout the Gulf of Mexico and Southern Atlantic seaboard. Hurricanes Gustav and Ike caused tens of billions of dollars in damage, much of which would have been reduced had larger barrier islands and a greater wetland buffer been in place. This first scenario continues the path of reducing natural hurricane buffering. The less nature does its work, the more FEMA will be needed.

The second scenario covers a suite of projects that aim to maintain the current amount of land across the delta so as to "hold the line" and prevent net land loss. The U.S. Army Corps of Engineers adopted this scenario in the 2008 Louisiana Coastal Protection Technical Report (LACPTR). Holding the line provides greater benefits than the first do nothing new, let-it-deteriorate scenario. This option prevents further collapse of the Mississippi Delta and the loss of at least $41 billion in ecosystem services. However, it does not significantly secure greater natural hurricane buffering than what was available the day Hurricane Katrina hit. It will leave New Orleans and other populated areas no better protected by natural systems. This scenario depends on larger and more expensive levees that actually require wetlands as buffers. Hurricanes Katrina, Rita, Gustav and Ike provided an important lesson, recognized by the U.S. Army Corps of Engineers, that levees protected by wetlands perform better and fail less than levees directly exposed to hurricane storm surges. Although this scenario takes into account some lessons from recent hurricanes, it does not grapple with the scale of the problem and potential for success. Deltas on the scale of the Mississippi River Delta are tremendously dynamic, either expanding or shrinking depending on the allocation of vast quantities of water and sediment. Attempting to "hold the line" is not realistic in a deltaic system of this scale. It is more difficult and more costly than actually re-establishing deltaic processes and using the energy and water of the Mississippi River on a larger scale to reap far greater benefits. The “hold the line” scenario is a better strategy than doing nothing but it is not systemic and provides too little investment in the Mississippi Delta. It does not solve the problem at the needed delta-wide scale.

The final scenario, sustainable restoration, implements large-scale, controlled diversions of water and sediment from the Mississippi River to reconnect it to the delta. This will gain ground, restore deltaic processes at the scale that the delta requires to stop land loss and maintain a net expansion of land. It will build a larger natural asset base and yearly provide greater ecosystem services, such as, fisheries production and direct expansion of hurricane buffering before hurricanes hit the levees and inhabited areas. Studies show that diversions and plant growth are sufficient to outpace the expected sea level rise that the Intergovernmental Panel on Climate Change has predicted. This scenario offers the best economic investment in terms of producing the greatest benefits in safety, economic viability and habitability of the Mississippi River Delta. It is also the most resilient option to uncertainty in natural systems, such as climate change and economic uncertainty. Initial investments in diversion structures utilize the energy of the Mississippi River and are inexpensive to operate over the long run.

The lands gained from this scenario will avoid the $41 billion in damage under scenario 1 and produce benefits with an estimated present value of at least $21 billion, bringing in an annual net benefit of $62 billion. This includes partial values of 11 ecosystem services. It does not include the value of increased protection for levees, or avoided catastrophic impacts such as levee breaching. It does not include the benefit of reduced displacement of residents, reduced FEMA, relief and recovery costs, lower insurance rates, lower national oil and gas prices, less litigation, or the benefits of an expanding coastal economy, greater employment, and stability gained for existing communities and residents.

A comparison of the three scenarios - with 27 other criteria including contribution to coastal stability, capacity to expand economic development and protection of water quality and energy infrastructure - show scenario 3 to have the highest ranking by far.

With an expanded Mississippi Delta, prevention of damage from levee failure or the protection of an existing levee infrastructure can provide benefits on the level of tens of billions of dollars in a single hurricane event. These values are difficult to estimate. However, it is clear that a strategy of gaining ground will provide critical natural goods and services such as public safety, storm protection, oil and gas and thereby expand the economic base of the Mississippi Delta and the nation. This is not a cut-the-river-loose scenario, but a managed system of diversions to use sediment and water to provide for public safety and economic benefits.

The economics is clear: invest in the Mississippi River rebuilding the delta to gain ground, physically and economically. On the other hand, ground loss results in loss of nature’s services, causing a hurricane-driven disorderly retreat inland and damaging people and businesses. This analysis strengthens ongoing planning by providing the economic justification for large-scale restoration. It complements efforts such as the State of Louisiana’s Comprehensive Master Plan for a Sustainable Coast and the Multiple Lines of Defense strategy developed by the Lake Pontchartrain Basin Foundation and Coalition to Restore Coastal Louisiana.

Academics, non-profit organizations, state officials, residents and just about every person who studied this issue carefully support the restoration of the Mississippi Delta. Gaining ground provides economic benefits by:

1. Rebuilding land with more than half of the Mississippi River's peak flow water and sediment;
2. Adding economic value including hurricane protection and protection of existing levees;
3. Spurring wetland plant growth soaking up carbon, increasing fisheries production and other benefits;
4. Building land with plant growth that beats sea level rise and land subsidence;
5. Helping stabilize barrier islands increases hurricane protection and coastal stability;
6. Reducing the "dead zone" in the Gulf of Mexico which will increase fisheries and other benefits;
7. Yielding greater ecosystem services for better water quality, wildlife habitat and hurricane protection;
8. Securing the nation's energy infrastructure and inhabitable area of the Mississippi River Delta;
9. Providing a more sustainable, vibrant economy with a higher quality of life; and
10. Setting an example for the nation, Gulf Coast and Eastern Seaboard in natural hurricane buffering.

The use of diversions for restoration is a proven strategy, not an experimental approach. Over 30 years of experience in water and sediment diversion shows that this strategy is successful in building land area and restoring wetlands. The Old River Control Structure diverts water and sediment down the Atchafalaya River; this results in the formation of new deltas in Wax Lake. The diversion at Caernavon is another success for rapid wetland expansion. These examples can be replicated on a much broader scale.

With such a wide range of economic benefits, this report provides a starting point to inform investments in levees, restoration, land use, and economic development in the Mississippi River Delta. This study provides the most comprehensive valuation of natural capital assets in the Mississippi River Delta to date; however, it is still a partial valuation and an underestimate of the delta's total potential economic value. This valuation does not include economically valuable benefits such as navigation, protection of oil and gas infrastructure, and aesthetic value. Even with a wide range of estimates, it points to critical tools that can better inform investments in levees, restoration, land use and economic development in the Mississippi River Delta.

This report shows conclusively that physical sustainability and delta expansion secures vast economic benefits locally and nationally. Within the context of the current financial crisis, investment in restoration secures short-term benefits of employment, income generation, greater ecosystem services and other economic benefits, and the long term goals of increased storm protection, greater oil and gas supply reliability and other economic benefits. A sustainable restoration of the Mississippi River Delta is a good investment with a high rate of return. Gaining ground is the most successful economic strategy for securing hurricane defenses and economic development.

Main Points

1. Mississippi River Delta ecosystems provide economically valuable services including hurricane storm protection, water supply, climate stability, food, furs, habitat, waste treatment, and other benefits worth at least $12-47 billion/year. These annual benefits provide a vast amount of value to people across time.
2. Estimates of the present value of the benefits from 11 Mississippi Delta ecosystem goods and services are between $330 billion and $1.3 trillion (3.5% discount rate).
3. Wetlands – a product of Mississippi River deltaic processes – which include freshwater, saltwater, estuaries, tidal bays, and cypress swamps account for more than 90% of the estimated total value of ecosystem services provided in the Mississippi Delta.
4. Large-scale physical changes are affecting the Mississippi River Delta. These are known facts: hurricanes have become larger and more frequent in the last 30 years, sea level has risen, atmospheric temperatures have risen, and the delta is subsiding and has lost over 1.2 million acres of land since 1930.
5. Three scenarios show that a “do-nothing” approach will cost at least $41 billion in damages. A “hold the line” scenario avoids the $41 billion, without additional benefits. A third “sustainable restoration” option will avoid $41 billion in losses and secure $21 billion in benefits, providing $62 billion in present value.
6. Science has established that large diversions of water and sediment from the Mississippi River are required to rebuild the Mississippi Delta and secure economic benefits.
7. Many ecosystem services with clear economic value could not be estimated in this study. Work is critically needed to further understand the benefits that investments in diversions, levees, or other structures produce.
8. Restoration of the Mississippi River deltaic processes requires a major investment to maintain or expand the vast value of this natural asset. The movement of water and sediment and the maintenance and expansion of land underlies the production of many economic benefits, including protection against hurricanes. Without this investment, people and economic assets will be forced to retreat from the coast.
9. Delta restoration must be based on ecological engineering. High and rising energy costs will erode the economics of energy intensive options such as levees and sediment pumping. Water and sediment diversions utilize the Mississippi River’s energy and can easily be maintained throughout many decades.
10. Within the context of the current financial crisis, investment in the restoration of the Mississippi River Delta provides high short and long-term returns. The Army Corps of Engineers, Federal, State and local governments should dramatically increase expenditures for the restoration of the Mississippi Delta.

List of Abbreviations

AC	Avoided Cost
CPRA	Coastal Protection and Restoration Authority
CV	Contingent Valuation
ESV	Ecosystem Services Valuation
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GNP	Gross National Product
GV	Group Value
HP	Hedonic Pricing
IPCC	Intergovernmental Panel on Climate Change
LCA	Louisiana Coastal Area
LSU	Louisiana State University
MRGO	Mississippi River Gulf Outlet
NOAA	National Oceanic and Atmospheric Administration
NPV	Net Present Value
PV	Present Value
RC	Replacement Cost
TC	Travel Cost
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

Introduction

"We are living in a historic moment, one that presents us with a stark choice: either make the bold and difficult decisions that will preserve our state's future, or cling to the status quo and allow coastal Louisiana to wash away before our eyes. There is no longer any time to waste. We must act now or forfeit the possibility that our children and grandchildren will be able to share the life, culture, and resources that are so precious to us and so important to the nation."

Coastal Protection and Restoration Authority of Louisiana, May 2007

A Rich and Enriching Delta

Landscapes, rivers and ecosystems are integral natural capital assets that influence, house, build and shape economies. The greatest concentrations of people and economic productivity have thrived along rivers, especially by coastlines and river deltas. Practically all major US cities have settled by rivers. Mississippi River, the longest in North America, has a basin that comprises 41% of the continental United States covering 1.2 million square miles. The water and soil of the Mississippi Basin flow, as they have for millennia, to the Mississippi River Delta[1] and into the Gulf of Mexico. Engineering on the Mississippi River over the years has removed sediment and water which once expanded the Mississippi River Delta. This has degraded vast areas of the delta and resulted in massive land loss.

The 9,600 square-mile Mississippi River Delta, one of the most productive and expansive river deltas in the world, is an invaluable part of America. Over 2.2 million people live in the delta.[2] The history, music, literature, cuisine, Cajun and Creole culture, and folk songs and stories of the Mississippi River Delta form part of the heart and soul of our nation.

The geology, climate, biological systems, and movement of water and sediment within the Mississippi River Delta sustain its economy and communities. The Mississippi River Delta has 40% of the United States coastal wetlands. It has provided the US and the world a vital navigation route to the mid-western states, oil and gas resources, pipelines, refineries, chemical and fertilizer industries, fisheries, forestry and agricultural production.

Healthy communities and economies need a well-functioning "natural capital", the stock of natural and ecological systems that yield a flow of ecological services and natural resources that benefit people.[3] River deltas shaped the world's first economies. Economies on river deltas expand or shrink with the delta.

Understanding the economic importance of natural capital in the Mississippi Delta requires an assessment of its economic productivity. More importantly, decisions that impact the delta's viability require measurement of the

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[1] Reference to the Mississippi River Delta in this report includes the Mississippi River deltaic and Chenier plains.
[2] U.S. Census, 2004
[3] Daly & Farley, 2004

value and benefits that this natural feature provides, such as storm protection, fisheries production, drinking water, recreation, wildlife habitat, and flood protection.

For the past eight decades, management of the Mississippi River Delta has had the primary goal of promoting shipping and the secondary goal of preventing flooding and storm damage. Today, an understanding of nature's contribution to the economy is fast emerging. A healthy economy requires the contributions that natural ecosystems provide, including oxygenated air, the protective ozone layer, a stable climate, clean water, land that does not sink, and protection from flood and storm. Forests, oceans, rivers, and land provide a vast array of benefits that are economically valuable assets.

Eighty years ago, the natural capital and benefits provided by the Mississippi River wetlands and barrier islands were so plentiful that they were viewed as limitless and deemed to be largely without value. Economic goals focused on the expansion of built capital, including roads, houses and levees. Today, built capital is abundant and more people have settled in coastal areas even as protective coastal features, such as wetlands and barrier islands have shrunk and hurricanes have grown stronger. Natural capital providing goods (fish, water) and services (storm protection, recreation) is now scarce and more valuable. The need to protect people and property against the destructive power of hurricanes, while increasing the stock of natural capital, has become more critical.

The barrier islands, coastal wetlands, swamps and uplands all provide buffering against hurricanes. Studies show that wetlands significantly reduce hurricane storm surge.[4] This and the value of other ecosystem services have not been counted as economic benefits. Neither were they included in flood and storm protection analyses that valued only built structures like levees. Valuable natural capital was then squandered. Land, barrier islands and wetlands were needlessly lost – as were the substantial benefits that these ecosystems provide, including hurricane protection.

The loss of valuable natural capital is a national trend, but change is afoot as new analyses and solutions are developed and applied. New Jersey became the first U.S. state to actually conduct a full economic analysis of its natural capital assets.[5] The Puget Sound basin was the first region with a valuation of 12 ecosystem services setting out a new vision of a local economy which includes the economic value of healthy natural systems.[6] On a local scale Earth Economics' recent study on the valuation of ecosystem services demonstrated that salmon restoration along the Green River in Puget Sound provides other ecosystem services, such as recreation and flood protection.[7] Six cities in the U.S., including Seattle, San Francisco and New York, filter drinking water through natural watersheds at costs that are far lower than what water filtration plants require. Most services that healthy ecosystems provide can be secured at far less cost compared to replacing these natural systems with built capital by incorporating these services (for instance, clean water or flood protection) in the management of utilities.[8] This study provides state of the art valuation methods to inform investment decisions.

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[4] Boesch et al. 2006, Day et al. 2007
[5] New Jersey Department of Environment Protection, 2007
[6] Batker et al. 2008
[7] Earth Economics, 2006
[8] Earth Economics, 2006

Knowledge of the Mississippi River Delta's economy is incomplete without measuring the economic productivity of the natural systems (natural capital) in providing hurricane storm protection, fisheries production, drinking water, recreation, wildlife habitat, flood protection and other benefits. Hurricanes Katrina and Rita demonstrated that natural, social and human capital have been undervalued in the decision making process and are now needed for economic analysis and for generating pragmatic and effective solutions.

Eyeing the Storms

Katrina first struck the U.S. near Florida's Broward/Miami-Dade County line as a category 1 hurricane on August 24, 2005. Fueled by the Gulf of Mexico's hot water, it quickly powered up into a massive category 5 hurricane. As Katrina moved inland, it crossed wetlands which then put more physical drag on the storm, slowed its progress, lowered the storm surge and reduced fetch (the area of open water where waves can gain in size and momentum). Figure 1 shows that as the hurricane hit the coastline, it quickly weakened to category 4 and then category 3 by the time it struck the Mississippi-Louisiana border on August 29, 2005 with sustained winds of 125 mph. The hurricane generated a storm surge that exceeded 30 ft along the Mississippi coast.[9] New Orleans experienced storm surges from 14-18 ft.

Figure 1. The track of Hurricane Katrina Showing Changes in Storm Intensity and Spatial Extent

Track of Hurricane Katrina, August 23-29, 2005, showing spatial extent and storm intensity along is path.

Source: NOAA

[9] NOAA, 2005; USACE, 2007

The hurricane storm surge flooding was most severe along the Mississippi coastline and in Louisiana communities where levees and floodwalls failed and wetland buffers had disappeared. Hurricane Katrina directly pummeled the Mississippi River Delta, affecting an area of over 90,000 square miles and over two million people. The communities most impacted include the Birdfoot Delta of the Mississippi River, the Mississippi coast, Slidell and surrounding areas, St. Bernard and Plaquemines parishes and New Orleans.[10]

Wetlands reduce hurricane impact. Hurricanes Katrina and Rita passed through areas of the Mississippi River Delta that had the greatest wetland loss between 1932 and 1990. This includes the Birdfoot Delta of the Mississippi River which lost 50% of its land area, St. Bernard Parish wetlands lost 17.0%, Plaquemines Parish lost 12.0% and the East Orleans land bridge lost 17.6%.[11] If the original wetlands still existed, they would have buffered the storm surge and both hurricanes would have caused far less damage.

Three weeks after Hurricane Katrina struck, category 5 Hurricane Rita cut a far larger swath of destruction, running parallel to the Gulf Coast stretching from Florida to Texas and again flooding parts of New Orleans. It made landfall near Sabine Pass at the Louisiana-Texas border with sustained wind speeds of 120 mph and a storm surge of at least 20 ft. Hurricane Rita's southeasterly approach resulted in a storm surge of at least nine ft that swept through the entire Louisiana coast.

In the 2008 hurricane season, Hurricane Gustav's faster speed in crossing the Gulf of Mexico fortunately prevented the storm from building up a larger storm surge. Had it moved more slowly, it would have generated and hauled a much larger storm surge across the gulf. Striking to the west of New Orleans, the storm surge of Hurricane Gustav was reduced by wetlands in its path. Gustav caused significant damage and again clearly demonstrated the importance of wetlands as barriers to hurricane storm surges.

The severity of hurricane damages in recent years have spurred a lively debate on the full impact of levees and built structures on storm surges. The Army Corps of Engineers now recognizes that the configuration of canals and levees can increase the damage caused by hurricane storm surges. For instance, the Mississippi River Gulf Outlet Canal (MRGO), dredged to provide an extra shipping canal for New Orleans, created a v-shaped funnel as wetlands in the center of the v-shape were lost due to salt water intrusion. Had these wetlands been intact, there would have been less flooding in southeastern New Orleans and St. Bernard Parish and the levee may have held and not been breached. However, as the storm surge waters of Katrina progressed from the wide-open mouth of the v-shape to its closed point, the levees constricted the storm surge waters and increased their height and destructive power. This flushed the storm surge's full force right into New Orleans, overtopping and demolishing the protective levees. This led the Louisiana Legislature and the U.S. Congress to order the permanent closure of the Mississippi River Gulf Outlet Canal. Plans to close the MRGO canal at the Bayou La Loutre ridge have been set.

Wetlands in the "land bridge" once provided a physical barrier to hurricane storm surge waters from the Gulf of Mexico entering Lake Pontchartrain. However, with the severe degradation of these wetlands, the storm surge

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[10] Cole, 2005
[11] USGS, 2002

of Hurricanes Katrina and Rita engorged Lake Pontchartrain, levees and sea walls failed below their rating, causing catastrophic flooding and killing people.

Levees can reflect and amplify storm surge waves, unlike wetlands that absorb and resist storm waters without amplifying wave action. The levee along the Birdfoot portion of the Mississippi River may have actually reflected Katrina's storm surge back to the Mississippi coastline, creating an additive effect and increasing the size and power of storm surge waves that struck the coast. The Army Corps of Engineers initially contested this view but accepted it as true after studying the similar effects from Hurricane Gustav.[12]

It is a clear fact that intact natural wetland ecosystems and other natural features provide hurricane protection. It is undeniable that the loss of barrier islands, wetlands, and land over the past several decades has made coastal residents far more vulnerable to hurricanes and storm surge damage. Louisiana lost over 1,875 square miles of wetlands and many of its barrier islands between 1932 and 2000.[13] After the hurricane season of 2005, this number rose to over 2,000 square miles or about 25% of total wetland area that existed at the turn of the century.

Public investment in the restoration of the Mississippi River can restore natural processes which generate real economic value in the form of hurricane protection, recreation, safe land for housing and industry and other benefits. Ignoring the degradation of the Mississippi Delta entails tremendous economic, ecological and social costs.

The Hurricanes' Economic Impact

Hurricanes Katrina, Rita, Gustav and Ike wrought heavy havoc along the U.S. Gulf Coast. Although the damage to built capital can be monetized, the human cost is incalculable. Hurricanes Katrina and Rita alone caused 1,815 deaths in Louisiana and Mississippi[14] with 705 people still deemed missing.[15] FEMA estimated the displaced people at two million in January 2006.[16] The hurricanes exposed the harsh reality of poverty and racism.[17] Neighborhoods and communities that were poor or African American or both still lie in ruin. Some coastal towns remain virtually abandoned. Hundreds of thousands of people remain displaced. The social fabric of the Gulf Coast is yet reeling from the storms' effects. Impeded by physical, legal and economic obstacles, full recovery has been slow to come.

Hurricane Katrina, the most costly natural disaster in U.S. history, caused $200 billion in property damages and economic losses.[18] Both hurricanes damaged 150 miles of levees to the point of requiring reconstruction; wrecked 360,000 homes, 504 schools, 97 hospitals, 570,000 cars, and 70,000 boats;[19] destroyed roads, bridges,

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[12] USACE, 2007
[13] USGS, 2003, also Boesch et al. 2006, Day et al. 2007
[14] Louisiana Department of Health and Hospitals, 2006
[15] Krupa, 2006
[16] Hsu, 2006
[17] Brown University, 2006
[18] U.S. Government Accountability Office, 2006
[19] FEMA, 2006

electric posts, telecommunications, water supply, sewerage, industrial areas, and playgrounds; caused 99% mortality in oyster beds with $1.1 billion in fisheries losses;[20] damaged 365,000 acres in 16 federal wildlife refuges, $1 billion in cropland losses;[21] and spilled 6.5 million gallons of oil.[22]

Property prices fell across the U.S. Gulf of Mexico while insurance rates rose.[23] Katrina shut down over 95% of offshore gulf crude oil production, roughly 27 % of total U.S. crude oil production. It broke pipelines and forced the shutdown of nearly a dozen refineries in eastern Louisiana, Mississippi and Alabama. Hurricane Rita forced the closure of 20 Texas and Louisiana refineries, accounting for more than four million barrels a day or more than 26% of U.S. refining capacity.[24] The disruption of oil and gas pipelines and oil refining in Louisiana caused a spike in the prices of natural gas, gasoline and other petroleum product throughout the U.S. Americans had to pay for the increase in the transportation costs of goods and people.

The increase in construction in Louisiana increased the cost of labor and materials by 20-40 % of the pre-2005 hurricane season; the nationwide increase was 5-10%. This dramatically increased the cost of recovery for insurers and owners across the Gulf Coast.[25] It also increased the price of building materials throughout the South. The legal aftermath of Hurricane Katrina promises to be as costly as the hurricane damage. Katrina produced an unprecedented number of lawsuits involving, among others, FEMA, the U.S. Army Corps of Engineers, levee boards, States, local governments, insurance companies, banks and homeowners.

While experts expect the damage from hurricanes to increase in the coming years, they also agree that this can be mitigated. The costliest hurricanes in history offer lessons we need to heed, the most important of which is the need to rebuild the delta at the scale that significantly reverses land loss.

Restoration Plans and Recent Legislation in Louisiana

Louisiana has developed restoration plans for the Mississippi River Delta. However, Hurricanes Katrina and Rita revealed that because of their limited goals for halting land loss, restoration plans such as the 1998 Coast 2050 Plan and the 2004 Louisiana Coastal Area Plan did not meet the scale of the problem. The Mississippi Delta is dynamic. It has consistently swung between gaining and losing land, but not to the extent of the net land loss in the past century. Meeting the goal of stopping land loss cannot be accomplished through levees and small projects. It requires a fundamental shift toward large diversions – moving vast quantities of water and sediment into the delta and out of the Mississippi River where it would be dumped off the continental shelf. Models and analyses of the impacts of wetlands and Hurricanes Katrina and Rita on flooding and storm surges now stress the need[26] to build land, sequester carbon and secure hurricane buffering and other services.

[20] Gaddis et al., 2005
[21] Center for the Study of Rural America, 2005
[22] EPA 2005
[23] Fletcher, 2005
[24] Federal Trade Commission, 2006
[25] McCormack, 2006
[26] Farley, Batker, & Pittman, 2006

In recognition of this weakness and in response to the 2005 storms, the Louisiana Legislature approved Act 8 creating the Louisiana Coastal Protection and Restoration Authority (CPRA) to develop and implement a comprehensive and integrated plan to restore the coastal wetlands and barrier islands. CPRA produced a master plan with the core objective to "Promote a sustainable coastal ecosystem by harnessing the processes of the natural system."[27] This plan outlines the need for a large-scale restoration of the Mississippi River Delta.

This objective includes the use of the Mississippi River's water and sediment to reestablish water flow and sediment delivery.[28] This comprehensive approach will provide a full basket of ecosystem service benefits including hurricane protection and flood protection, internationally significant fish and wildlife habitat, water quality, regionally and nationally important port facilities, navigable waterways, fuel processing capacity and the unique culture of the area.[29] Effective coastal restoration calls for a recognition of how the economy is dependent on a stable, healthy and expanding Mississippi Delta.

The State of Louisiana is moving forward with a new vision of restoration in the Mississippi Delta. In addition, citizen's organizations such as the Lake Pontchartrain Basin Foundation and Coalition to Restore Coastal Louisiana have outlined a Multiple Lines of Defense strategy, which also restores basic deltaic processes and is integrated with levees and built structures to provide effective hurricane protection.[30] However, the investment resources for implementing a comprehensive restoration are lacking. Understanding the importance of natural capital to the local and national economy is a relatively new revelation in economics. It provides a new view of the economy and a better insight into the local and national value of investing in natural capital.

Part I: A New View of Value in the Mississippi River Delta

The field of economics has advanced significantly in recent years improving our ability to quantify the value of goods and services provided by nature. These advances include new concepts and techniques such as "natural capital" and ecosystem service valuation. The sophistication and applicability of ecosystem service valuation has also rapidly expanded.[31] This section provides basic concepts and methods used for assessing the value of ecosystem services in the Mississippi River Delta.

Natural Capital

Natural Capital and Asset Management

In the 1930s, human-built capital was scarce; the expansive wetlands of the Mississippi River Delta were considered a wasteland. Natural goods sourced in the wetlands such as timber, fish and oil were viewed as limitless. Economic development was seen as the conversion of otherwise untapped natural resources into built capital or useful marketable goods. However, natural systems produce benefits and public goods – such as

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[27]Coastal Protection and Restoration Authority, 2007a
[28] CPRA 2007a
[29] CPRA 2007a
[30] Lake Pontchartrain Basin Foundation, 2008
[31] Limburg, O'Neill, Costanza, & Farber, 2002

breathable air and hurricane protection – without human labor, fees or restriction (everyone can breathe the air and everyone living behind wetlands receives storm protection). Because these "public goods" cost nothing and could not be privatized or traded in markets, they were deemed to have no economic value. Today, however, markets produce a vast abundance of goods such as cloths, toys, asphalt and food for a lower real cost while nature's goods and services have become relatively scarcer and increasingly valuable. Given the loss of healthy ecosystems, the valuation of natural capital helps decision makers identify costs and benefits, evaluate alternatives and make effective and efficient management decisions. Excluding natural capital in investment decisions or asset management can result in significant losses, increased costs (public and private) and decreases in efficiency and community benefit.

Understanding Natural Capital

Natural capital is comprised of the geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continuing return of valuable benefits.[32] It contributes to our economy and quality of life in many ways that are not currently included in market transactions or policies. In fact, most decision makers and the citizens are not aware of the full economic value of natural systems. Natural capital contributes to the provision of water, natural water filtration, energy production, flood control, recreation, natural storm water management, biodiversity, discovery of new medicines, and education. Ecosystems are defined as all the interacting living and nonliving elements of an area of land or water. Ecosystem functions refer to the processes of transformation of matter and energy in ecosystems. Ecosystem goods and services are the benefits that humans directly and indirectly derive from naturally functioning ecological systems.[33] They are the flux of value provided from intact natural capital to people. For something to be classified as an ecosystem good or service, it must benefit people.

The Economics of Natural Capital

Healthy ecosystems are self-maintaining. They have the potential to appreciate in value over time and to provide an ongoing output of valuable goods and services in perpetuity. In contrast, built structures and other man-made capital depreciate in value over time and require capital investment, operations and maintenance. The provision and filtration of water is a good example.

The city of New York requires a daily supply of more than one billion gallons of water. Facing degraded drinking water quality, New York City weighed its options between building a water filtration plant costing over $6 billion and that of investing $1.5 billion to restore the health of the watershed thereby allowing natural processes to filter the water and meet drinking water standards. The city decided to invest in the watershed. Investment in restoration has proved to bring a far higher rate of return; it is less costly and less risky for meeting standards. The cities of Seattle, Tacoma, Portland and San Francisco have maintained forested watersheds that supply water at above drinking water standards. With forests filtering water for drinking, the cities of Seattle and Tacoma have avoided capital construction for water filtration plants that would have cost $250 million and $150 million respectively. In addition, filtration plants would require maintenance and replacement while the forest is essentially a self-maintaining water supply and filtration system. If the value of

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[32] Daly & Farley, 2004

[33] Costanza et al., 1997; Daily, 1997; De Groot et al., 2002; Wilson, Troy & Costanza, 2004

these ecosystems is not recognized and they are degraded, we may well lose these critical benefits and be forced to replace least-cost natural systems with more costly built capital replacements.

Ecosystems and Value

Ecosystems and Value Production

Ecosystems are comprised of structural components (trees, wetland plants, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, reduced fetch, obstructions to hurricane storm surges, etc.) that generate ecological goods (fish, timber, water, oxygen) and services (hurricane and flood protection, water filtration, recreation, aesthetic value, etc.). Figure 2 below summarizes these relationships in a simplified diagram.

Ecosystem infrastructure has particular physical components such as the salt, brackish, intermediate and fresh marshes and swamps of the Mississippi Delta. The infrastructure itself is dynamic; biotic structures migrate and abiotic components flow through the delta, often via air or water. For example, the lobes of the Mississippi River Delta show great dynamism in the deposition of historical sediments. These functions vary widely in spatial boundaries (oxygen migrates globally while shrimp spawning and production are confined locally). Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production). These structures, processes and functions combine to produce economically valuable goods and services.

Figure 2. Relationship of Ecosystems to the Goods and Services Produced

Valuation of Ecosystem Services

Ecosystem service valuation assigns a dollar value to goods and services provided by a given ecosystem. This allows for proposed management policies to be considered in terms of their ability to improve ecological processes that produce the full diversity of valuable ecosystem goods and services. This study will provide the low and high value estimates for some of the goods and services provided in the Mississippi River Delta.

Ecosystem Goods and Their Valuation

Most goods that the Mississippi River Delta provides – such as water, timber, fish, and furs – are excludable. If one individual owns or uses a particular good, that individual can exclude others from owning or using the same. For instance, if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets.

The production of goods can be measured by the physical quantity produced by an ecosystem through time. This is known as a flow of benefits; for instance, the volume of water production per second, the board feet of timber production in a 40-year rotation, or the weight of fish harvested each year. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. This production creates a flow of economically valuable ecosystem goods over time.

Ecosystem Services and Their Valuation

Ecosystem Services Defined

Ecological services are defined as "the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life."[34] Ecosystems provide a variety of services that individuals and communities use and rely on, not only for their quality of life but also for economic production.[35] Ecosystem services are measurable benefits that people receive from ecosystems.

The stream of services provided by an ecosystem, referred to as a "service flux," cannot be measured as the physical quantity of a product produced, and is then far more difficult to measure and value. Examples of this are the hurricane buffering of wetlands, water filtration and recreational value.

Most ecosystem services are non-excludable. Wetlands provide hurricane buffering to all who live behind them, aesthetic value to anyone who looks at them, and flood protection for everyone living downstream. Due to this non-excludability, most ecosystem services cannot be traded or sold in markets.

Table 1. Examples of Ecosystem Services

Examples of Ecosystem Services
Purification of the air and water
Mitigation of hurricanes, floods and droughts
Recreation
Detoxification and decomposition of wastes
Generation and renewal of soil and soil fertility
Pollination of crops and natural vegetation
Control of the vast majority of potential agricultural pests
Dispersal of seeds and translocation of nutrients
Maintenance of biodiversity
Protection from the sun's harmful ultraviolet rays
Partial stabilization of climate
Moderation of temperature extremes and the force of wind and waves
Support of diverse human cultures
Provision of aesthetic beauty

Source: Daily et. al, 1997

[34] Modified from Daily et al., 1997
[35] Daily, 1997; Costanza et al., 1997

Structure and Value Production

The quality, quantity, reliability and combination of goods and services that the ecosystems in the Mississippi Delta provide depend on the structure and health of these ecosystems. Structure refers to a specific arrangement of ecosystem components. For instance, the steel, glass, plastic and gasoline that comprise a car must retain a very particular structure to provide transportation service. These very same components cannot provide transportation without a car's structure. Shrimp require certain ecological processes, structures and conditions. Ecological service production is more dependent on structure than the flows of goods. A single species timber plantation may yield a flow of goods (timber) but it cannot provide the same service fluxes (biodiversity, recreation and flood protection) as an intact natural forest.

Integrated Ecosystems and Multiple Benefits

A heart or lungs cannot function outside the body. Neither can the human body function without a heart and lungs. With all the organs functioning, a body can perform many tasks. Good bodily health requires organs to work as part of a coordinated system. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts. When separated, each of the physical and biological components of the Mississippi Delta would not be capable of generating the same goods and services that the processes and functions of an intact watershed system provide.[36] The sheet flow of water across the Mississippi Delta for example, maintains wetlands across salinity gradients. Intact ecosystems provide a full basket of goods and services. The Mississippi Delta provides fish, land for habitation and industry, storm protection, clean water, recreation and flood control. Built structures, such as levees or fish hatcheries, may replace only one function, but not the full basket of goods and services. Ecosystems are engines of economic productivity and systems of significant complexity. Individual services influence and interact with each other, often in nonlinear ways. They may collapse if they are stressed beyond critical thresholds. For example, the "dead zone" is an area the size of New Jersey, off the outlet of the Mississippi River created by the nutrient load, plankton bloom and oxygen depletion. This productive area has collapsed ecologically and economically.

Resilience

Resilience refers to the potential of a system to return to a previous state after disturbance. A system is assumed to be fragile when resilience is low. Fragile systems tend to be replaced after disturbance, for example wetlands are converted to open water which produce reduced amounts of ecosystem services and provide less economic value.[37] While symptoms of disturbance may appear when an ecosystem is on the verge of collapse, with the exception of a few well-studied systems,[38] there is little science available to show the minimum threshold of ecosystem infrastructure that is needed to stop the breakdown of services. Likewise, ecosystems have been shown to be quite resilient; in some cases, ecosystem health improves when restoration projects are initiated. Wetlands in coastal Louisiana provide a great example. Thresholds of stress cause loss of large areas of wetlands. Experience in rebuilding wetlands with renewed inputs of sediments and nutrients from the Mississippi River have secured greater resiliency.[39] Subsidence, a natural process, is a characteristic of the Mississippi Delta and all major deltas. It is the lowering of the surface of the land due to compaction,

[36] EPA, 2004
[37] Gunderson & Holling, 2002 also Day et al. 1997
[38] Carpenter & Gunderson, 2001
[39] Tibbets, 2006

consolidation and dewatering of sediments.[40] In order to survive subsidence, wetlands must build upwards at the same rate that the land is sinking and sea level is rising (this is called relative sea level rise or RSLR). Under natural conditions, the Mississippi Delta was highly dynamic and resilient. The delta loses wetlands in some areas and gains in others, but expanded overall despite subsidence and sea level rise. The elimination of sediment and water from the river to most of the delta (it was channeled by levees off the continental shelf) initiated the collapse of wetlands with pervasive changes in hydrology.

Value Production in Perpetuity

The Mississippi Delta has contributed to human economies for thousands of years. This is evidenced by numerous sites where Native Americans lived. Healthy intact ecosystems are self-organizing (require no maintenance) and do not depreciate. They can provide valuable ecological goods and services on an ongoing basis "in perpetuity." A forest can provide water control, flood protection, aesthetic and recreational values, slope stability, biodiversity, water filtration and other services without maintenance costs. This differs from human-produced goods and services (cars, houses, energy, telecommunications, etc.) that require maintenance expenditures, dissipate, may depreciate and usually end up discarded, requiring further energy inputs for disposal or recycling. The benefits that a natural capital provides can be quickly and permanently lost with mismanagement. The loss of an ecosystem's natural flood or storm prevention functions will result in large, long-term and accelerating costs to private individuals, businesses, communities and governments. They either suffer increased storm and flood damage or pay for expensive and often less effective engineering solutions. As the health of ecosystems decline, the natural and economically valuable services are lost. Taxpayers, businesses and governments then incur damage, repair or replacement costs and higher insurance premiums (or loss of access to insurance). When ecological services are restored, the reverse dynamic can occur.

Greatly altered or degraded ecosystems, like those in the Mississippi River Delta, require a combination of built structures, such as water and sediment diversion structures, to restore natural processes and provide the greatest benefits for people. Understanding the value of natural capital is important for all decision makers, from individual residents to corporations, and local and federal governments. All hold assets, earn income, or participate in the long-term economic planning for the region; all would be better off knowing the importance and value of Mississippi River Delta natural systems.

23 Ecosystem Services

De Groot et al. categorized ecosystem services based on the processes and functions they perform to the benefit of humans (see Table 2).[41] Grouped into four categories (regulation, habitat, production, and information), these functions amount to 23 ecological services. The regulation and habitat functions are considered essential before production and information functions can be active.[42] The following table defines and describes ecosystem services that flow from most ecosystems, including those in Coastal Louisiana. The next section gives a more detailed description of wetland ecosystem services.

[40] Day et al. 1977
[41] De Groot et al. 2002
[42] De Groot et al. 2002; Wilson et al. 2006

Table 2. Categories of Ecosystem Dynamics with Corresponding Goods and Services

Functions		Ecosystem Infrastructure and Processes	Examples of Goods and Services
Regulation Functions		*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles	Provides clean, breathable air, disease prevention, and a habitable planet
2	Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favorable climate promotes human health, crop productivity, recreation, and other services
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	Prevents and mitigates natural hazards and natural events that are generally associated with storms and other severe weather
4	Water regulation	Role of land cover in regulating runoff and river discharge	Provides natural irrigation, drainage, channel flow regulation, and navigable transportation
5	Water supply	Filtering, retention, and storage of fresh water (e.g. in aquifers and snow pack)	Provision of water for consumptive use, includes both quality and quantity
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	Maintains arable land, prevents damage from erosion, and promotes agricultural productivity
7	Soil formation	Weathering of rock, accumulation of organic matter	Promotes agricultural productivity and the integrity of natural ecosystems
8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients	Promotes health and productive soils; gas, climate, and water regulations
9	Waste treatment	Role of vegetation and biota in removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification; filtering of dust particles through canopy services
10	Pollination	Role of biota in movement of floral gametes	Pollination of wild plant species and harvested crops
11	Biological control	Population control through trophic-dynamic relations	Provides pest and disease control, reduces crop damage
Habitat Functions		*Providing habitat (suitable living space) for wild plant and animal species*	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity; thus the basis for most other functions
13	Nursery function	Suitable reproduction habitat	Maintenance of commercially harvested species
Production Functions		*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits, etc.; small scale subsistence farming and aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing; fuel and energy; fodder and fertilizer
16	Genetic resources	Genetic material and evolution in wild plants and animals	Improves crop resistance to pathogens and pests
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs, pharmaceuticals, chemical models, tools, test and assay organisms

18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration and souvenirs
Information and Cultural Functions		*Providing opportunities for cognitive and spiritual development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Source: De Groot et al. 2002

Because decisions turn out to be very costly when the contributions of natural capital to economic activity are not counted,[43] interest in identifying, describing and quantifying the economic value of ecosystem services to improve decision making have increased through the years.[44] This is particularly relevant in coastal areas given that preliminary estimates of the global economic value of coastal (including large estuaries) and marine ecosystems show that are two-thirds of total ecosystem service value of all systems on earth.[45] It is crucial to understand how economic value shifts with changes in natural systems, especially along coastal systems with high development and extraction pressures.[46]

Deriving economic values for ecosystem services is a complex undertaking. Ecosystem services are different from private goods because they do not easily lend themselves to pricing and markets.

Ecosystem functions, and the services they produce, result from broad interactions across large landscapes (e.g., storm buffering) or, in some cases, the whole planet (e.g., climate and carbon sequestration). These interdependent systems make life possible; providing for climate, oxygen, nutrient cycles, water and energy flows, and the movements of seeds. This interdependence and tremendous scale of operation makes nature the best producer of these goods and services. It would be impractical and undesirable to attempt to set up human institutions, markets and factories to provide for global climate regulation, oxygen production and provision of water. [47] It is far better economics to avoid wrecking productive natural systems, or to restore them when damaged, than attempt to displace or do without them.

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[43] Daly & Farley, 2004
[44] Daily, 1997; Costanza et al., 1997; Balmford et al., 2002
[45] Costanza et al., 1997; Costanza 1999
[46] UNEP, 2005
[47] Daly & Farley, 2004

Natural systems like the Mississippi Delta are part of our common wealth. Many are ***public goods and services***. Ascribing economic value to these ecosystem services helps policy makers and the public decide how to allocate public funds for the common good.[48]

Valuation Techniques

Ecosystem goods and services may be divided into two general categories: ***market*** and ***non-market***. Measuring market values simply requires monitoring market data for prices and quantities sold. This production creates a flow of ecosystem goods that have a market-defined economic value over time.

The non-market values of goods and services are more difficult to measure. When there are no explicit markets for services, the more indirect means of assessing values must be used. Table 3 identifies a spectrum of valuation techniques that are commonly used to establish values when market values do not exist. It also summarizes the appropriateness of each technique for different types of services.

Table 3. Valuation Methodologies

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; storm protection provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC): services can be replaced with man-made systems; nutrient cycling waste treatment provided by wetlands can be replaced with costly treatment systems.
Factor Income (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and the incomes of fisherfolk.
Travel Cost (TC): service demand may require travel whose costs can reflect the implied value of the service; recreation areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it, including the imputed value of their time.
Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods; for example, housing prices along the coastline tend to exceed the prices of inland homes.
Marginal Product Estimation (MP): service demand is generated in a dynamic modeling environment using a production function (Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.
Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay for increased preservation of beaches and shoreline.
Group Valuation (GV): this approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate*.

Source: Costanza et al. 2006

[48] Costanza, 2006

Table 4. Appropriateness of Valuation Methodologies for Ecosystem Service Type[49]

Ecosystem Service	Amenability to Economic Valuation	Most Appropriate Method for Valuation	Transferability Across Sites
Gas regulation	Medium	CV, AC, RC	High
Climate regulation	Low	CV, AC, RC	High
Disturbance regulation	High	AC	Medium
Biological regulation	Medium	AC, P	High
Water regulation	High	M, AC, RC, H, P, CV	Medium
Soil retention	Medium	AC, RC, H	Medium
Waste regulation	High	RC, AC, CV	Medium to high
Nutrient regulation	Medium	AC, RC, CV	Medium
Water supply	High	AC, RC, M, TC	Medium
Food	High	M, P	High
Raw materials	High	M, P	High
Genetic resources	Low	M, AC	Low
Medicinal resources	High	AC, RC, P	High
Ornamental resources	High	AC, RC, H	Medium
Recreation	High	TC, CV, ranking	Low
Aesthetics	High	H, TC, CV, ranking	Low
Science and education	Low	Ranking	High
Spiritual and historic	Low	CV, ranking	Low

Adapted from Farber et al. 2006

These tables show that each valuation methodology has its own strengths and limitations, often limiting its use to a select range of ecosystem goods and services within a given landscape. For instance, the value generated by a naturally functioning ecological system in the treatment of wastewater can be estimated by using the replacement cost (RC) method which is based on the price of the cheapest alternative for obtaining that service (the cost of chemical or mechanical alternatives). A related method, avoided cost (AC) can be used to estimate value based on the cost of damages due to lost services. This method was used to value the flood protection services provided by restored habitats and functions within the flood plain. Travel cost (TC) and contingent valuation (CV) surveys are useful for estimating recreation values while hedonic pricing (HP) is used for estimating property values associated with aesthetic qualities of natural ecosystems. Contingent valuation surveys and conjoint analysis can be used to measure existence value of ecosystems and charismatic animals. Marginal product (MP) estimation has generally been used in a dynamic modeling context; it helps examine how ecosystem service values change over time. Finally, group valuation (GV), a more recent addition to the

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[49] This table is adapted from Farber et al. 2006. Some changes are based on our opinion on appropriateness of some techniques for some services.

valuation literature, directly addresses the need to measure social values in a group context. In many applications, the full suite of ecosystem valuation techniques will be required to account for the economic value of goods and services provided by a natural landscape.

Not all ecosystem services listed in Table 4 were readily valued; for some services no valuation studies have yet been conducted. Very important services such as climate regulation, genetic resources, and spiritual and historical significance have low valuation amenability. In addition, nutrient cycling usually receives relatively low values even though life on the planet would not be possible without it.[50]

The diverse structures and processes associated with the landscapes creating ecosystem goods and services that benefit people are linked together. Once valuable ecosystem services are identified, values for some of these goods and services can be assessed where valuation techniques exist. It is easier to note that a service is valuable to people than to attach a dollar value to it. In economic terms, the natural assets of the landscape can yield direct (fishing) and indirect (nutrient regulation) use values as well as non-use (preservation) values of the system. Once accounted for, these economic values can be aggregated to estimate a more complete value of benefits that the landscape provides.

Methodology

Value Transfer Method

A value transfer study appraises the value of ecosystem services in a geographic area based on previously conducted primary valuation studies. Individual primary valuation studies are generally conducted for one or a small number of services in one ecosystem or land-use type using the methods described above. These local studies are precise for individual ecosystem services, but are incomplete, lacking the scope across ecosystems and services necessary to be instructive for policy work at a landscape scale. Conducting primary research for the Mississippi River Delta and examining a wide number of ecosystem services across ecosystems would require over 50 primary studies to cover the full suite of ecosystem services across each vegetation type. It would require an enormous budget and take many years of research. Primary studies are required, and must proceed. The need for more comprehensive value estimates of these values, which can be useful for policy decisions, gave rise to the value transfer method.

Value transfer method involves using existing on-site or, if unavailable, off-site primary valuation studies or data to estimate the value of ecosystem services. Following Desvouges et al., this study uses the term 'value transfer,' instead of the more commonly used term 'benefit transfer,' to reflect the fact that the transfer method is not restricted to economic benefits and can include the analysis of potential economic costs as well as value functions themselves. The transfer method involves obtaining an economic estimate for the value of non-market services through the analysis of a single study, or group of studies, that have been previously carried out to value similar services. The transfer itself refers to the application of values and other information from the original 'study site' to a new 'policy site'.[51]

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[50] UNEP, 2005

[51] Desvouges et al., 1998; Loomis 1992; Smith 1992

This methodology is much like a house appraisal. An appraisal is conducted to provide an estimate of the house's value before the house is put up for sale. A very rough "appraisal" of the house's value can be provided by examining the values of similar houses in the neighborhood or other similar areas and by taking into account particular characteristics, such as an extra bedroom or a bad roof.

Public agencies are increasingly using the value transfer method to inform landscape management decisions.[52] Despite acknowledged limitations, such as context sensitivity of value estimates, existing studies provide a credible basis for policy decisions involving sites other than the study site for which the values were originally estimated. Using the studies that bound low and high values reflects the uncertainty that is implicit to using valuation studies that are older or from another site. The critical underlying assumption, just as in a house appraisal, is that a range in the economic value of ecosystem goods or services provided by existing valuation studies can encompass the site value with sufficient accuracy to be useful. Without this methodology, decision makers have in effect ascribed a zero value to natural services over the past decades.

The accuracy of the value transfer technique improves with increases in the richness, extent and detail of information of the source literature.[53] With the increasing sophistication and number of empirical economic valuation studies in peer-reviewed literature, the value transfer method has become a practical way to inform decisions when budget and time constraints preclude full primary data collection.[54] Although the literature is yet far from complete, the Mississippi River Delta has one of the world's richest collections of primary research on ecosystem service valuation for wetlands. The reference section includes studies by Day, Costanza, Farber, Boesch and others.

There are two parts to this economic analysis. The first part shows the value of ecosystem services from wetlands, with some of the data filled in with studies from wetlands other than the Mississippi River Delta. We also provide similar value transfer results from ecosystem services for non-wetland ecosystem types within the coastal zone that will be affected by loss of wetlands and will therefore be less habitable in the coming decades. Ecosystems and their services will be less valuable to people in the coastal areas if they can no longer live there. Many ecosystems are already less functional, as in the case of fresh water lakes, due to wetland loss and saltwater intrusion.

We then synthesize results and primary data on wetlands functions and values to come up with a value for the specific ecosystem services and functions for which there is Louisiana-specific information. This approach leads to a range of values that carry fewer uncertainties associated with economic results transferred from different sites. These results are underestimates; they provide a high quality "lower bound" set of values of ecosystem services for coastal wetlands in the Mississippi River Delta.

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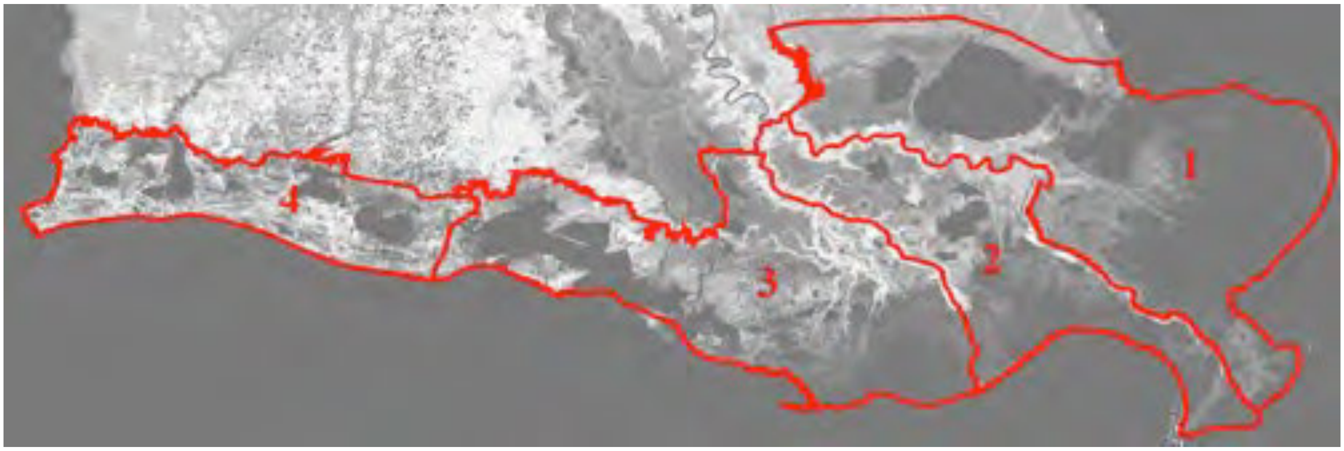
[52] Downing & Ozuna, 1996; Eade & Moran, 1996; Kirchoff et al., 1997; Smith, 1992, Troy and Wilson, 2006
[53] See Spash and Vatn, 2006 for an alternative perspective
[54] Kreuter et al. 2001; Moran 1999

Area of Study and GIS data

Figure 3 shows the geographic boundary of our study area. The Mississippi Deltaic Plain (Units 1-3) and the Chenier Plain (Unit 4) are divided into four subprovinces or units by the U.S. Geological Survey and the State of Louisiana. This includes the wetlands and upland ecosystems that are valued in this study.

Figure 3. Geographic Boundary of Study Area



Source: USGS

Units 1, 2 and 3 form part of the Mississippi River Delta while unit 4 holds the Chenier Plain. All four units comprise the Mississippi River Delta in this report.

Geographic Information Systems (GIS) data for six wetland types in the four subprovinces of the Mississippi Deltaic and the Chenier Plains were used based on 2000 data provided by the US Geological Service.[55] Table 5 shows acres of wetland type by subprovince.

Table 5. Acres of Wetland by Type and Subprovince

Subprovince	Fresh Wetlands	Intermediate Wetland	Brackish Wetlands	Saline Wetlands	Shrub/Scrub Wetlands	Wetland Forest
1	75,388	137,084	154,070	126,484	31,268	345,465
2	168754	78,650	63,603	123,327	22,260	286,864
3	337,266	277,118	134,583	31,032	16,915	10,416
4	295,690	168,080	195,189	140,717	50,823	388,815
Total	**877,099**	**660,933**	**547,445**	**421,561**	**172,106**	**10,311,561**

[55] Kreuter et al. 2001; Moran 1999

Ecosystem Service Valuation Studies

Ecosystem service values were derived from delta-specific data for eight ecosystem services. These are carbon sequestration (gas regulation, see Table 1), water quality (nutrient regulation), water supply, fisheries (food provisioning), fur and alligator production (raw materials production), recreation (cultural and information services), storm protection (disturbance regulation) and cultural value. Details of how we calculated service values or which ones we chose from the literature follow. Louisiana-specific data were not available for all ecosystem services. To provide a more complete estimate, the values for other ecosystem services were based on studies conducted outside Louisiana. Part II of this study discusses the valuation of ecosystem services.

PART II: The Value of Mississippi River Delta's Natural Capital

Mississippi River Delta Ecosystem Services

Below are descriptions of the subset of the ecosystem services identified in Table 2, which were considered in this study. The function of the ecosystem service and the economic value derived are discussed. Ecosystem services often have multiple benefits within each category; it may be possible to value only one or two of these multiple benefits. For example, while wetlands may provide recreation in the form of hunting, fishing, boating, birding and swimming, only one of these benefits may have actually been quantified. This is one reason economists typically view most valuation estimates as conservative.

Water Supply

While some rely on groundwater, most communities in southern Louisiana rely on fresh surface water for their water supplies. Wetlands protect the water supplies of coastal communities by preventing the intrusion of salt water into surface and groundwater supplies. As wetlands retreat, saltwater moves through open water areas where wetlands once existed or seeps into freshwater aquifers, contaminating surface and underground waters. Farber estimates the cost for groundwater-dependent communities to develop alternative sources under future wetland loss scenarios. Farber uses the replacement cost method for groundwater-dependent communities to develop pump and main infrastructure that would deliver water from other communities.[56]

Laska notes that communities that depend on surface water from rivers and bayous rely on coastal wetlands to prevent saltwater intrusion. Laska does not provide economic value estimates for this service. Wetland loss will mean increased salinity problems for these communities.[57] Figures for this service were derived from the replacement cost of desalinization plants for 19 coastal parishes in Louisiana and the population of 2.2 million people they serve. Desalinization of brackish water is less expensive than estuarine saltwater. Assuming that the average American uses 90 gallons of water per day, this amounts to an annual 72.3 billion gallons of water use in the Louisiana coast. Using figures from the American Water Works Association, a "low" cost of $1.50/1000

[56] Farber, 1996
[57] Laska, 2005

gallons and a “high” cost of $4/1,000 gallons were established. This gives values of $46.67 and $124.47 on a per acre-year basis in 2007 dollars.[58]

Some economists argue that replacement costs provide “upper bound” estimates of ecosystem services values. The replacement cost method is appropriate for valuing the water supply functions of the Mississippi River Delta’s wetlands because there are no other alternatives except human-engineered replacements for the provision of freshwater to many communities. In addition, human-built systems, such as a desalinization plant, are more vulnerable to hurricanes damage. Thus the replacement costs may be considerable underestimates because a plant may be destroyed prior to the expected lifetime of the facility. Built replacement options, such as desalinization, are in fact more vulnerable to damage or destruction under conditions of wetland loss. Thus, replacement cost method for human-engineered systems may greatly underestimate the true costs of supplying drinking water.

Water Quality (Nutrient Regulation)

Excess nitrogen, phosphorous, bacteria such as fecal coliform, and other pollutants in water reduce the quality of water for drinking, recreation, agriculture and industrial purposes. Wetlands have a very high capacity to absorb and process excess nutrients as well as destroy harmful bacteria. The Mississippi Delta wetlands absorb nutrients and reduce the “dead zone” or hypoxic area in the Gulf of Mexico (further discussed below). Wetlands are eutrophic systems that are able to process large quantities of nitrogen and phosphorous and rapidly sequester carbon. These benefits are provided throughout the Mississippi Delta.

Many coastal Louisiana studies have examined nutrient removal, primarily as a substitute for tertiary sewerage treatment by towns and industries particularly using swamp forests.[59] Wetland-based filtration provides the benefit of being much less energy intensive than “traditional” wastewater treatment;[60] it can also increase the growth rates and carbon sequestration[61] by bald cypress.[62] More than 15 communities in coastal Louisiana have wetland assimilation systems. These systems proved to be far more resilient to hurricane damage than traditional systems. New Orleans is now pursuing what will be the largest wetland treatment system in the U.S.; it will use wastewater to fertilize 30,000 acres of bald cypress swamp that will in turn be a critical hurricane buffer for the city.

Economic values for wetlands depend on state and federally imposed water quality standards. Most rely on the replacement cost method. These regulatory water standards are attempts to internalize pollution costs and are related to the socially acceptable levels of health standards. Farber provided an extrapolation of the benefits of nutrient removal for all towns in the coastal wetland zone where treatment is a viable option.[63] This study did not include New Orleans, which is adopting wetland sewerage treatment. Rather than per-acre values, he used present value for the entire coastal wetland zone under different discount rates. In a literature review, Kazmierczak provided mean, median, upper and lower bound (the Farber paper) per-acre estimates of the value

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[58] AWWA, 2007
[59] Breaux, Farber & Day, 1995; Cardoch, Day & Kemp, 2000; Kazmierczak, 2001; Day et al., 2004; Ko et al., 2004
[60] Ko et al., 2004
[61] Millennium Ecosystem Assessment, 2005
[62] Hesse Doyle & Day, 1998
[63] Farber, 1996

of wetlands for water quality ($2.85-$5,674/ac-yr range; $975 mean, $281 median for Louisiana 2000 dollars; 2007 are $3.44, $6,832.35, $1,217.96, and $338.37).[64]

Using wetland assimilation also reduces CO_2 release to the atmosphere because these systems are much more energy efficient. Thus wetland assimilation reduces CO_2 release because these systems are more energy efficient. It also enhances carbon sequestration through below and above ground plant growth.

The gulf hypoxic zone at the mouth of the Mississippi River is a related nutrient management problem for the Gulf Coast. Mitsch et al. estimate that reconnecting the Mississippi River to its floodplain would absorb 50,000-100,000 metric tons of nitrogen per year.[65] Nitrogen enrichment also enhances tree stem growth by 23-80%, increasing carbon sequestration.[66] Shrinking the hypoxic zone would also improve fisheries productivity. The complexity between weather and climate patterns, hypoxic zone size, wetland loss, individual species life cycles and habitat requirements make fisheries improvement difficult to estimate.[67] Thus, despite the high likelihood of an important economic linkage between hypoxia and fisheries an estimate on the value of shrinking the hypoxic zone to improvements in fisheries is not included here. This value is highly spatially dependent, with high-value areas for treatment concentrated around human settlements and industrial areas, and likely lower background values for hypoxia reduction throughout the wetlands.

This analysis uses the median $281/acre as a low value and $1,217.96/acre as a high value. There are studies that show far higher values for effluent treatment services. For instance, the $6,224.27 derived from a commercial potato chip plant for effluent treatment is too specific and too small a scale to extrapolate to the entire Louisiana coastal zone.

Fisheries Production

Costanza et al. use a production function developed by Lynne et al. for fisheries production in Louisiana where catch predictions are based on marsh acreage and catch in the previous year and harvesting effort in the current year.[68] Costanza et al. estimate that the per-acre wetland value for brown and white shrimp, menhaden fish, oyster and blue crab total to $25.36/acre/year using 1983 prices ($48.10 2004 dollars).[69] Farber estimates per-acre values of $36.93-$51.52 in 1990 dollars ($58.58 low, $81.73 high in 2007 dollars).[70] Since Farber's range of estimates includes those of Costanza et al., we used Farber's low value for the low value for this category. These figures do not include all of the fish and shellfish species and production from the Mississippi Delta nor the value of fish reared in the Mississippi Delta but caught elsewhere in the Gulf of Mexico. More recent fisheries data available from several sources[71] can be used to update the estimates from Costanza et al. and Farber. Thus, these provide good estimates of the lower boundary. For the high value, the meta analysis mean

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[64] Kazmierczak, 2001
[65] Mitsch et al., 2001
[66] Day et al., 2003
[67] Chesney et al. 2000
[68] Lynne et al., 1981
[69] Costanza et al., 1989
[70] Farber, 1996
[71] See Chesney et al. 2000, Gramling and Hagelman 2005, Lindstedt 2005

for the fisheries production value of wetlands derived from an econometric analysis of 39 studies is adapted from Woodward and Wui at $1,233.49 in 2007 dollars.[72]

Raw Materials: Wild Fur and Alligator Production

Many raw materials produced in the Mississippi Delta, including timber, are not included in the value for this study. For this category, only fur and alligator production was included from the harvest estimates of the Louisiana Fur and Alligator Advisory Council that keeps annual harvest data by species. Assuming that muskrats come from brackish and intermediate marsh, nutria and raccoons from freshwater marsh, and alligators from fresh, intermediate and brackish marsh, harvests for these species can be valued on a per-acre basis. The 2004-2005 harvests and prices provide the low values for this category while the 10-year average values from 1995-1996 to 2004-2005 harvests and prices provide the high values.

Costanza et al. previously used estimates of 0.98 muskrat pelts/ac from brackish and intermediate marsh, and 0.88 nutria pelts/acre from freshwater marsh. They use 1980-1981 values of $6 per muskrat pelt and $7 per nutria pelt, for a total value per acre of $12.04.[73] However, the fur market collapsed in 1987-1988, making these values inappropriate for today's use. More recent data show values of over $1 million per year for trapping pelts and meat between 1993 and 2002 in Louisiana.[74] Of this harvest, 71% of commercial value came from nutria, 18% from raccoon, and 11% from other mammals, including muskrat. The low value used in this study is $4.74/acre/year and the high is $5.38/acre/year.

Carbon sequestration

Carbon sequestration as used in this study refers to the ability of vegetation to take up carbon dioxide through photosynthesis and store it for long periods of time in their woody tissues, in the soil, or in both. There are two parts to valuing carbon sequestration: establishing how much carbon is sequestered each year and establishing a dollar value for that sequestration service.

Herbaceous wetlands store large amounts of carbon in the soil while forested wetlands store it in both woody tissue and in the soil. Chmura et al. found median carbon uptake rates for all wetland types and the median carbon uptake rate to be 186 g/m^2/year. The uptake was greater in fresh to intermediate marsh than in brackish to salt marsh. Fresh and intermediate marsh had lower soil carbon density.[75] Choi et al. found far higher soil carbon sequestration rates than Chmura in salt marsh (2900 g/m^2) and in brackish to intermediate (1300-1500 g/m^2).[76] These results are specific to the Barataria Basin in coastal Louisiana. These marshes had the Net Primary Productivity (NPP) of 1,000-4,000 g C/m^2-year. This is much greater than that of the surrounding upland forests, which are estimated at 200-1,000 g C/m^2-year. Due to sulfate reduction, salt marshes do not generate significant methane. Yu et al. showed that mature Louisiana swamp forests accumulate

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[72] Woodward and Wui, 2001
[73] Costanza, Farber & Maxwell, 1998
[74] Lindstedt, 2005
[75] Chmura, 2003
[76] Trulio, 2007

carbon, but that atmospheric methane release offset these gains.[77] Sea level rise may cause upland forests to transition into swamp forests, affecting their greenhouse gas balance. Day et al. showed tree stem growth enhancement of 23-80% under enhanced nutrient conditions in swamp forests.[78] Day and Kemp[79] have produced more recent estimates of marsh and wetland forest carbon sequestration rates which show degraded marsh sequestering 4.5 tons CO_2/acre/year, healthy marshes sequestering 11 tons CO_2/acre/yr, and wetland forests sequestering 10 tons CO_2/acre/year with forests enhanced with waste assimilation sequestering up to 25 tons CO_2/acre/year including both above and belowground sequestration. Full analysis with methane production is not yet complete.

There is a significant range in carbon sequestration depending on the health of the wetland or forested wetland. For this study we use the Day et al. low value, which assume that all wetlands are in a degraded state of 4.5 tons CO_2/acre/year for the low value of all wetland types and shrub/scrub wetlands. This study uses 11 tons CO_2/acre for the marsh high value, which is also in line with the findings of Choi et al. We use the Day et al. value of 10 tons CO_2/acre/year for the high and low of wetland forest carbon sequestration as this includes both above and belowground sequestration.

For a dollar value per ton of CO_2 sequestered, a low value of this service inclusive of both a market and social cost is provided by Pearce & Pearce who recommend the use of $10/ton ($11.71 in 2007 dollars) of carbon sequestered as a conservative estimate.[80] Such a market does not exist yet.[81] The Stern Report, probably the most widely quoted economic report on climate change, established a social cost value of $85/ton. This value is used for the high value.[82]

Market prices for a ton of carbon based on voluntary markets fluctuate dramatically, making it difficult to determine a clear market value for CO_2. Being voluntary and without full participation of all CO_2 emitters, the market price of the Chicago and European trading systems do not reflect full market prices. Both markets have fluctuated greatly. At the European Union Emissions Trading Scheme, carbon prices rose to $36/ton early in 2006 and fell to under $3/ton by spring 2007.[83] The Chicago Climate Exchange priced carbon at $4/ton in 2007 and $8/ton in 2006.[84] Voluntary carbon markets in the United States have sold carbon "offsets" at prices ranging from $5-25/ton with an average of $10/ton.[85]

Although carbon markets are yet at early stages of development, the science is clear. Removing carbon from the atmosphere will reduce global warming and help secure the valuable ecosystem service of better climate stability reducing draught, floods, storms and broad climate shifts.

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[77] Yu & DeLaune, 2006
[78] Day et al., 2003
[79] Day and Kemp manuscript
[80] Pearce & Pearce, 2001
[81] Zhang (2000) provides similar estimates for an "ideal" global market - at $11.23-14.74/ton C.
[82] Stern Report
[83] Ecosystem Marketplace, 2007
[84] Chicago Climate Exchange, Mar. 2006; Chicago Climate Exchange, Sept. 2006
[85] Clean Air-Cool Planet, 2006

Recreation

Numerous studies have estimated the recreational benefits of coastal Louisiana's wetlands. Most of these studies give a present value for each acre of wetlands or the entire coast. Since Bergstrom et al. provide a per-acre-year value and the different studies find values to be similar, Bergstrom's value of $147.57/acre/year is used here.[86]

Bergstrom et al. similarly used TC and CV across seven parishes. They estimated a value of $224.21/ha-yr for marshland only in the study area ($147.57/acre/year in 2007 dollars). Bergstrom et al. stratified their sample for sites in fresh and saltwater marsh, at high and low-density recreation sites and across an east-west gradient. Unfortunately only total values were reported since these would be useful distinctions for recreational valuation across coastal Louisiana. Farber modeled recreational loss under wetland decline as a function of willingness to pay, quality of the experience and population, and projects declining values as fishing and hunting quality falls.[87] Bergstrom et al. found values for fishing on the lower Atchafalaya almost identical to Bergstrom et al. 1990, supporting the use of similar values for the entire Louisiana Coast.[88]

Storm Protection (Disturbance Regulation)

If there is one area that exemplifies the rapid increase in value of ecosystem services, it is storm protection value. It also shows how our understanding of ecosystem services improves with time as wind and storm surge damage area included in the most recent analysis. Storm protection refers to the function of wetlands in reducing storm energy and storm-generated water surges that cause flooding. This ecosystem service is very important to residents of the Mississippi Delta, the Gulf of Mexico and U.S. Eastern Seaboard.

Farber and Costanza first estimated wetland value for hurricane protection from wind damage at $63,676/mile strip of wetlands (1980 dollars), with a present value of $23/acre discounted at 3%.[89] Martinez et al. developed a study about the coasts of the world, estimating a value for the ecosystem services provided by terrestrial and aquatic ecosystems. They estimate in 2004 dollars $\$436.3*10^9$ per kilometer per year for permanent wetlands in terrestrial ecosystems and $\$24,364.72*10^9$ per kilometer per year for the whole aquatic ecosystem including coral reefs, mangroves, sea grass, coastal shelf, swamps-floodplains and estuaries.[90] Costanza et al. provide estimates for both wind and flood damage; Farber provided estimates for capital, land and maintenance costs associated with levee construction and property loss from wetland disintegration.[91]

In a 2008 study, Costanza et al[92] provide the most timely and accurate value estimates for storm protection values. Their analysis includes Hurricanes Katrina and Rita. They use estimates of spatially explicit GDP (flows of value from built capital at risk) along with storm probabilities to model value per hectare for gulf and Atlantic coast states. They estimate the value of wetlands for storm protection in Louisiana at $3,446/hectare/year (2007 dollars - $1,530.82/acre). It is highly probable that this figure will rise with Hurricane Gustav. Future

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[86] Bergstrom & Stahl, 1993; Bergstrom et al., 1990
[87] Farber, 1996
[88] Bergstrom et al., 2004; Bergstrom et al., 1990
[89] Farber & Costanza, 1987
[90] Martinez et al., 2007
[91] Costanza et al., 1989; Farber, 1996
[92] Costanza et al., 2008

estimates may refine values spatially by examining the differences in built capital across Louisiana's coast from east to west.[93] Given the importance of the 2008 Costanza et al. study, we appended their methods section to this report.

Our understanding of the storm protection value of wetlands is increasing rapidly. Wetlands tend to be most effective at reducing the storm surge of hurricanes where the storm surge is most intense. Thus, they likely provide a higher value than estimated here. In addition, the vegetation of wetlands reduce hurricane storm surge in three ways: they reduce the height of the storm surge directly with the drag of vegetation thus holding water back, they physically slow the movement of the storm surge forward thus allowing for greater dissipation of the storm surge, and they physically rob the hurricane of the ability to pull up water into the storm surge.

Wetlands reduce the wave action of the storm surge, thus protecting levees from pounding waves and increasing the effectiveness and lifespan of levees. The full value of these preventative and protective benefits has not been fully valued. Costanza's analysis provides a tremendous improvement and is the best estimate of the value of wetlands for reducing storm surge to date.

Other important ecosystem services for which adequate results or data from Louisiana could not be found include aesthetics, habitat for threatened and endangered species, and cultural values. Values from other studies on wetland ecosystems from other parts of the country and of the world were substituted to provide estimates for these services.

Other Wetland Ecosystem Values

Values for endangered species habitat[94] and aesthetics,[95] adjusted to 2007 dollars per acre per year, were adopted from original peer-reviewed studies. Values for gas regulation (distinct from carbon sequestration) and water flow regulation were adjusted to 2007 dollars per acre from 1994 dollars per hectare.

Water Flow Regulation: Flood Protection

Wetlands provide protection from the wind and storm surge of hurricanes from the Gulf of Mexico and flood protection from waters flowing from the Mississippi River Basin. Across a geographic area the physical functions provided by the wetlands may be similar. However, the valuable service provided to people varies with where people live and the value to them. Value is then distinct from function. This section discusses the flood protection value of the Mississippi Delta, which is unique in North America due to the size of its drainage area and the levees on the Mississippi River. Both built structures and natural ecosystems in the Mississippi Delta provide flood protection benefit for areas downstream and for the cities upstream in the Mississippi Basin by receiving floodwaters out of the Basin and effecting more rapid drainage.

The Mississippi River used to flood 50 miles wide on either side of the river. Over the decades the Army Corps of Engineers has leveed the main stem of the Mississippi River and separated the river from the wide flood

[93] Costanza & Farley, 2007
[94] Kazmierczak, 2001b
[95] Thibodeau, 1981; Mahan, 2000

plain. In addition the Corps corked rivers that distributed water out of the main stem of the river and into wetlands and the Gulf of Mexico. The 2008 record flooding along the Mississippi River in the Midwest was not caused from water rushing down and flooding cities from the upper watershed down, but from the Mississippi River backing up into tributaries to flood cities like Cedar Rapids, Iowa. This flooding results from engineering actions like confining the river too tightly within levees and separating the river from its floodplain. All the surface water that flows through the 1.2 million square miles of the Mississippi River Basin draining over 40% of the continental U.S. is funneled to the Old River Control Structure in Louisiana. Before the levees were built, the Red River and many other rivers branched off from the Mississippi River to distribute water across the Mississippi Delta. Tributaries are rivers that come together to form a larger river while distributaries are rivers branching out in the delta to distribute the river's waters and sediment across the delta.

The Old River Control Structure divides the waters of the Mississippi River sending them down two great distributaries, not yet cut off by levees, the lower Mississippi River and the Atchafalaya River. They finally enter the Gulf of Mexico at the Birdfoot outlet and Wax Lake Delta. River diversion structures act as controlled distributaries letting water and sediment flow into the deltaic plain and reducing flooding on the main stem upstream and downstream. Diversions increase the capacity of water and sediment to escape into wetlands, which then lowers the main stem water level allowing floodwaters further upstream to drain more quickly. Wetlands both absorb water and further move water in a sheet flow toward the Gulf of Mexico. This also reduces damage to levees and flood protection structures upstream and downstream.

During flood periods, the Old River Control Structure diverts far greater amounts of water and sediment down the Atchafalaya River and through a vast floodway and expanse of wetlands to relieve flooding pressure far upstream in the Mississippi River and to protect New Orleans and other cities downstream. Mississippi Delta wetlands provide high value flood protection by receiving these floodwaters. Without this "uncorked" area available to contain a tremendous quantity of floodwaters, flooding would be greater and longer lasting in the Midwestern U.S. Ultimately cities like Chicago are dependent on the Mississippi Delta as the outlet for water and some flood reduction benefits. Both in water quantity and the vastness of area served, the Mississippi Delta is absolutely unique in the provision of flood protection in North America.

In addition, although coastal areas are sparsely populated, the value of these wetlands may be more similar to wetlands providing benefits to urban areas. The Mississippi Delta houses extremely high value oil and gas infrastructure. Delta wetlands protect oil and gas production facilities, pipelines and refineries providing over a quarter of U.S. domestic oil and gas supplies. Wetlands provide flood and storm protection to oil infrastructure by reducing erosion and damage to pipes buried within the wetlands and by buffering other infrastructure from flood (and storm) waters. Hurricane Katrina revealed the vulnerability of both gas and oil pipelines by devastating enormous areas where oil and gas pipes had been exposed through wetland loss. Katrina caused 44 oil spill incidents with over seven million gallons of oil spilled.[96]

The full flood protection value of Mississippi Delta wetlands cannot easily be separated from the built structures, such as the Old River Control Structure and levees. There is great debate on how much local flood protection levees provide during low flood years and how much flooding they cause during peak flood years,

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[96] Llanos, 2005

like 2008 and 1993. Despite the critical importance of flood protection for safety and economic assets, few studies on wetland flood protection value exist.

There are no ecosystem service valuation studies in Louisiana that show the high value flood protection benefits of Mississippi Delta. In addition, there are no studies that examine flood protection over great landscapes such as the Mississippi River Delta or the extensive upstream flood protection benefits. There are no studies examining the value of these wetlands for protection of oil and gas infrastructure. The few studies that do exist primarily examine flood protection benefits provided by wetlands to nearby urban areas. The full flood protection that the Mississippi Delta provides upstream and downstream to public safety and economic assets such as oil and gas assets is perhaps one of the most important studies yet to be conducted.

The lack of local studies poses a problem in placing a dollar equivalent to the extensive flood protection value that the Mississippi Delta natural systems provide. This presents a difficult choice between excluding the value of a clearly high value ecosystem service the Mississippi Delta provides and using values from studies in other locations for comparison. How applicable these comparative studies are depends on the ecosystem service, the vegetation type and the site. Carbon sequestration provides a case of easy transferability. For instance, although they may be of different locales, similar forest ecosystems of similar structure and growth rates provide equal carbon sequestration functions. Carbon sequestration is of value in stabilizing the climate anywhere it takes place. The value is not dependent on the location. Here studies from distant but similar systems likely describe the value of carbon sequestration very well. Endangered species habitat, however, is more unique. The value of preserving one endangered species habitat on one continent may not transfer to another entirely unique species' habitat elsewhere.

The analysis in this paper is partial. More than a dozen ecosystem services identified as present and valuable in the Mississippi River Delta are not valued. This is largely due to a lack of local or comparable valuation studies. Overall, the study, analogous to a house appraisal, is an inexact approximation. In the authors' view, it is better to include an imperfect comparable value, than to simply give a highly valuable and clearly present asset a value of zero.

The flood benefit studies used in this analysis are for wetlands providing flood benefits to urban areas. These are wetlands in close proximity to urban areas with high value infrastructure. Although freshwater, intermediate and brackish wetlands all provide the function of flood protection, freshwater wetlands are most closely associated with urban areas. They also provide the greatest upstream flood relief, as in the case of the Atchafalaya basin. In this study, the greater values for flood protection are attributed only to freshwater wetlands and not to intermediate, brackish, or salt marshes.

A study by Thibodeau[97] values the flood protection of wetlands outside Boston at $6,539.19 per acre in 2007 dollars. Another study in Washington State examined two wetland areas (one near the city of Renton and the other near Lynnwood) establishing a per acre values with a low of $8,000/acre and a high of $51,000/acre.[98]

[97] Thibodeau et al., 1981
[98] Leschine et al., 1997

Flood and disturbance protection value is provided by all of the wetlands where they are protecting people, towns, oil and gas or other infrastructure. In this study, the mean value from Woodward and Wui was applied for the low value and the $6,539.19 value from Thibodeau was applied as high value for fresh marsh, shrub and forested wetlands. These wetlands are further inland and tend to be closer to cities and other built infrastructure; they contribute to the protection of cities further up the Mississippi Basin. Brackish and saline marsh still protect high value oil and gas infrastructure, towns and businesses on the coast; lower values based on the low values from Woodward and Wui were thus applied to these areas.[99]

Habitat Refugium

The Mississippi Delta is a tremendous area for aquatic and terrestrial wildlife. The area is a critical and irreplaceable stopover for migratory North American birds. The area provides valuable habitat to a number of endangered and threatened species. In addition, by providing sufficient habitat to keep other species off the threatened and endangered species lists, the Mississippi Delta relieves other jurisdictions in the continental U.S. of costly expenditures that would arise if these species were listed. No full study of the value per acre of provided by the Mississippi Delta exists. However, Kazmierczack provides the figures used here as the low and high values of $203.63/acre/year and $485.92/acre/year.

Upland Ecosystems

Despite the substantial number of economic valuation studies that have been completed for coastal Louisiana's wetlands, less work has been done for the region's upland ecosystems. As an initial effort to assess values for upland areas, the value coefficients from a project at the University of Vermont to estimate ecosystem service values for the state of New Jersey were utilized.[100] Although New Jersey has a different ecoregional and socioeconomic setting, it is a coastal U.S. state whose natural capital base faces pressure, albeit largely from development and not wholesale wetlands decline. The studies selected for the New Jersey value transfer exercise were selected from across the U.S. including some from the Mississippi Delta.

To round out our estimate of the value of Mississippi River Delta's natural capital when local data was not available and when other values were not present, the values from Costanza et al. were used[101] for the ecosystem services that more recent studies did not cover. Although these numbers are likely less accurate, we chose to use all available data to get a more complete picture and estimate. The greatest error of most valuation studies has been the omission of values for clearly valuable ecosystem services, thus significantly underestimating the value of benefits that ecosystem services provide to people. Further refinement of the value estimates for these upland ecosystems will improve the value estimates for the Mississippi River Delta. All values were converted into 2007 dollars using the Bureau of Labor Statistics' Consumer Price Index.

It is important to note that this study does not pick a single number as a value, it establishes a low and high value range. This helps us understand some of the inherent uncertainty held in this process. The most prevalent

[99] Woodward and Wui, 2001
[100] Costanza et al., 2006a
[101] Costanza et al. 1997

error is that of omission; for instance, agricultural land provides greater benefits but few studies examining them exist.

Although these express the range of possible values for each land cover type, each estimate is a composite value for all relevant ecosystem services where data is available; it is unlikely that a particular ecosystem would have the highest or lowest values for all ecosystem services.

Results and Discussion

Land cover Types, Ecosystem Services and Dollar Value Estimates

The next three tables provide an overview of results. Table 6 shows values per acre (in 2007 dollars) for all land cover types including wetlands and all ecosystem services for which data is available. It shows the dollar value per acre of each ecosystem service for each land cover type. The highest values per acre are provided by fresh water wetlands and forested wetlands at $3,200-12,000. All natural systems provide economic benefits. For some systems, there is far more valuation data available than for other systems. Generally, estuarine and open water systems are far less studied than wetlands and forested systems. Water regulation and storm protection benefits have the highest values per acre. Flood prevention and hurricane protection are two of the most important functions of coastal systems in the Mississippi Delta.

Forested wetlands provide the significant value for both low and high values in the Mississippi Delta. This is directly tied to the physical functions of these forests. Wetland forests provide strong hurricane protection value by slowing and reducing the storm surge and breaking up hurricane force winds at the surface where it is most important. Bald Cypress trees, for example, are excellent hurricane buffers because they are well buttressed by an extensive root system that provides tall, sturdy and highly resilient barriers to wind and water. They have evolved to withstand strong wind and water action. All of the marsh types provide hurricane buffering. Salt, brackish and intermediate marshes provide greater buffering value along the coastline. More research is needed to fully understand the mechanics of natural systems in buffering hurricanes.

The color codes in Table 6 correspond to the general source of academic valuation studies. Green indicates numbers derived from local Mississippi Delta data. We used other study references where there was no local data. Purple corresponds to figures used in the 2005 New Jersey study, most of which were derived outside New Jersey. Blue corresponds to the Kazmierczack 2001 wildlife value study. Pink corresponds to Costanza (1997) and yellow to studies from the Gund Institute for Ecological Economics database. Appendix A contains all of the references for the value transfer studies from which each of these figures is derived. Appendix B provides a table of the land cover type, authors, the type of valuation analysis conducted (one of seven valuation study types, avoided cost, contingent, etc.) and the high and low values in 2004 dollars which corresponds to the values in Table 6 (converted to 2007 dollars).

The greatest source of error is introduced by lack of data. Many of the boxes in the table are empty. In many cases, economically valuable services are clearly provided but no valuation studies have been conducted. This is the case for over 50 clearly valuable ecosystem service/land cover type combinations such as the value of wetlands for erosion control. Thus the high and low values are likely underestimates of the true high and low values of these systems. In a few cases, the service may not be provided, for example pollination in marine environments. Because there were no newer and better studies, many of the studies used here are over a decade old. Despite these shortcomings, this table to date provides the most comprehensive accounting of ecosystem services provided by the Mississippi Delta.

Table 6. Per Acre Values for Land Cover Types and Ecosystem Services in the Mississippi River Delta (2004 Dollars/Acre/Year)

	Fresh Wetland		Intermediate Wetland		Brackish Wetland		Saline Wetland		Shrub-scrub Wetland		Forested Wetland		Open Fresh Water		Open Estuarine Water		Upland Shrub-Scrub		Upland Forest		Pasture/ Agriculture Land	
Ecosystem Service Type	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Carbon Sequestration	35.14	382.52	35.14	382.52	35.14	382.52	35.14	382.52	52.71	382.52	117.12	850.05					5.81	7.32	11.60	14.63		
Atmospheric Composition Regulation	149.99	149.99	149.99	149.99	149.99	149.99			149.99	149.99	149.99	149.99					3.96	3.96				
Waste Treatment	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	376.70	376.70			49.28	49.28	49.28	49.28		
Water Supply	46.67	124.47	46.67	124.47	46.67	124.47	46.67	124.47	46.67	124.47	46.67	124.47	30.24	788.82	6.07	131.49			9.88	422.61		
Water Flow Regulation	612.14	6,539.19	141.27	612.14	141.27	612.14	141.27	612.14	612.14	6,539.19	612.14	6,539.19					1.70	1.70				
Storm Protection (Disturbance Regulation)	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82							1.13	1.13		
Food Production	58.59	1,354.00	58.58	1,354.00	58.58	1,354.00	58.59	1,354.00	58.58	1,354.00	58.58	1,354.00	23.23	23.23					28.32	28.32	34.28	34.28
Raw Materials Production	4.75	5.38	4.68	4.76	4.68	4.77			4.68	4.76									14.16	14.16		
Recreation	205.74	644.20	205.74	644.20	205.74	644.20	205.74	644.20	205.74	644.20	205.74	644.20	1.58	1,794.37	11.88	1,425.07	14.35	1,198.56	0.40	2,368.84	28.29	28.29
Aesthetic	74.74	239.07	74.74	239.07	74.74	239.07	74.74	239.06	74.74	239.07												
Pollination																	1.24	6.22	64.76	290.89	2.47	12.45
Soil Formation																	0.56	0.56	5.66	5.66	0.56	0.56
Nutrient Cycling																			204.49	204.49		
Erosion Control																	16.42	16.42	54.38	54.38		
Biological Control																	13.32	13.32	2.26	2.26	13.32	13.32
Genetic Resources																			9.08	9.08		
Habitat Refugium	203.63	485.92	203.63	485.92	203.63	485.92	203.63	485.92	203.63	485.92	203.63	485.92			1.39	365.30	0.60	298.26	1.15	596.51		
Cultural																						
Total	3,230.67	12,629.60	2,759.73	6,701.94	2,759.73	6,701.94	2,605.06	6,547.19	3,248.17	12,628.99	3,233.16	12,852.69	431.78	2,983.12	19.34	1,921.86	107.20	1,595.60	456.55	4,062.24	78.90	88.88

Table 7 shows the land cover types, acres of each land cover type, low and high value estimates per acre, and the sum of ranges in value these vegetation types provide on the Mississippi Delta. Thus, this study presents the low and high value estimates of ecosystem services that the Mississippi River Basin provides in one year. The range between the high and low total values – $25 billion – is substantial and reflects the uncertainty and differences in valuation studies. Both the low and high values are large and demonstrate that the natural systems in the Mississippi Delta provide valuable economic benefits. These natural systems are also highly efficient at providing this value. To replace them with built capital alternatives would be far more costly or impossible. In addition, if restored to health, these natural systems are self-maintaining and can, without charge, provide services, such as hurricane buffering.

The large values of wetlands and wetland forests in the Mississippi Delta primarily come from the water regulation and hurricane protection. These areas deserve further study. As is the case with all economic measures, this measure of value is not perfect. Like other aggregate economic measures such as the Gross Domestic Product, or total assessed property values, this analysis takes the marginal value per unit (dollars per acre) multiplied by the total number of units (acres) to estimate a “gross” total value. A better, far more difficult, and not yet developed measure would consider the dynamic nature of the change in value as trade-offs between these land cover types takes place. The Gund Institute for Ecological Economics is developing dynamic tools for this purpose.

The spatial distribution of services is another difficult issue. Not every acre of wetland provides equal amounts of storm protection value, as was assumed here. Because every storm differs in location, intensity, storm surge, wind speed, aspect to the coastline etc., the value of wetlands for storm protection will be different for every storm. With greater Geographic Information System data, and better predictive data on hurricane strength, location and occurrence as well as land cover types along the expected hurricane route and the lives and value of property protected would provide the basic information needed to improve this valuation. One advantage to increased coastal wetlands, as opposed to levees, is that a wide skirt of wetlands provides buffering against hurricanes approaching from any angle, speed, or storm surge height. The cumulative nature of wetland protection value is also not measured here.

Every individual acre of wetland provides differential benefits. As better techniques for valuation become available, this differential value will be better measured. However, most economic measures, such as the gross domestic product (GDP), are incapable of accounting for this individual difference in expressed value. Every new automobile of an identical make also provides differential benefits. For example, consider two new trucks of the same model sold for the same price, one performs poorly while the lasts for decades. They are valued identically in the GDP. A more useful economic measure of value would be based on the actual economic performance and benefit provided by each truck (analogous to the actual value an acre of wetland provides for hurricane protection). However, this would be impossible to calculate. Imperfect as it is, the GDP is a useful aggregate measure of value. Similarly, this report provides an aggregate value of natural systems in the Mississippi River Delta that can be improved upon. Although the values provided here are underestimates of the true value Mississippi Delta ecosystems provide, they meet the same basic standard of accepted economic measures and are certainly better than nothing.

Based on available data, the value of the services examined here and provided by the Mississippi Delta is estimated between $12-47 billion annually. Retaining and expanding this annual flow of benefits is good economics. Unfortunately, these benefits have been largely counted as zero for most of the last century.

Table 7. Total Value Based on Acreage for Each Ecosystem Type (2007 Dollars)

Land Cover Type	Acres	Low Value Estimate	High Estimate
Fresh Water Marsh	877,099	$2,833,616,569	$11,077,411,806.55
Intermediate Marsh	660,933	$1,823,993,642	$4,429,535,089.73
Brackish Marsh	547,445	$1,510,797,014	$3,668,942,825.58
Saline Marsh	421,561	$1,098,191,310	$2,760,038,549.65
Shrub-scrub wetland	172,106	$393,890,419	$1,531,460,185.19
Forested/Swamp Wetland	1,031,561	$3,335,203,387	$13,258,333,954.99
Open Fresh Water	992127	$428,346,204	$2,959,631,369.64
Open Estuarine Water	3,549,990	$68,661,717	$6,822,566,401.65
Upland Shrub-Scrub	84,799	$9,090,572	$135,305,795.41
Upland Forest	172,106	$78,575,469	$699,135,025.33
Pasture-Agriculture	481,575	$37,997,389	$42,802,567.96
Total	8,940,461	$11,953,060,333	$47,385,163,571.67

Table 8 shows the equivalent of an asset value for the economic benefits derived from Mississippi Delta's natural systems. This is the present value of the flow of benefits from these services in a 100-year period, shown for the four discount rates. The asset value of Mississippi Delta ecological systems (a partial value since not all ecosystem services were valued) varies from $237 billion at the low end using a 5% discount rate to $4.7 trillion if the benefits to people in the future are treated equally to the benefits we receive in the present over a 100-year period. This demonstrates that the natural capital asset value of the Mississippi River Delta is tremendous by any measure.

Since open water provides fewer benefits than land in this area, continued land loss will result in a decline in asset value. In addition, the dead zone reduces the value of estuarine waters within the area of study, thus providing a lower value. The reduced value on account of the dead zone was not included. The reality is that all ecosystems in the Mississippi Delta contribute value to citizens both within the delta and the nation. Local, state and national investment decisions should be informed by the value of natural capital.

Table 8. Present Value of Ecosystem Services over 100 years (2007 dollars).

Discount Rate	Low Estimate	High Estimate
0 %	1.2 trillion	4.7 trillion
2 %	513 billion	2.3 trillion
3.5%	330 billion	1.3 trillion
5%	237 billion	940 billion

The differences between these values depend on the discount rate chosen, as shown by Table 8. How value across time is treated, particularly in respect to renewable resources that provide value across vast amounts of time. A short discussion of how an "asset" value is calculated from the value of annual benefits that the Mississippi Delta provides and some of the implicit issues behind the choice of a discount rate follows.

The difference between an annual flow of benefits and an asset value is often not intuitive to non-economists. Consider first that ecosystems provide an annual flow of benefits, some of which can be expressed in dollar value as shown in Tables 6 and 7. From this annual flow of value, the value of the asset or the structure that produces that value can be estimated. This is analogous to comparing an annual mortgage payment for a house (the value of living in the house for a year) and the total "asset value" or price of the house.

A natural capital asset value is *analogous* to a built capital asset value because unlike a house or car, ecosystems the size of the Mississippi Delta cannot be bought or sold as a whole asset and because many of the most important benefits are public goods and services which by their physical nature (like oxygen in the air or hurricane buffering) cannot be bought or sold in markets. However, just as the value of a "built capital" asset can be calculated from the annual flow of net income it produces (annual flow of value) a "natural capital" asset value of the Mississippi Delta can also be calculated from the estimated annual flow of benefits that it provides.

Calculating the present value of an asset requires the use of a discount rate. Discount rates measure the extent to which people value benefits in the present versus benefits at a future date. Current environmental economics literature yields a healthy discussion about whether or not to use discount rates and what rate should be applied to calculate the value ecological assets over time;[102] there is a variety of alternatives to standard exponential discounting, including using declining rates[103] and "intergenerational" discounting which allows the assignment of different, lower discount rates for future generations versus the current generation.[104]

Renewable resources should be treated with lower discount rates than built capital assets because they provide a rate of return over a far longer period of time (potentially thousands of years or longer, for example, the ozone

[102] Azar and Sterner, 1996
[103] Newell and Pizer, 2003
[104] Sumaila and Walter, 2005

layer). It would be unwise and a tremendous economic blunder to treat value across time for the ozone layer's protection the same way we treat the useful life of a throwaway coffee cup. The discarded coffee cup provides no value to our grandchildren. Since the value of the ozone layer and a coffee cup are fundamentally different in importance and value to people across time, a coffee cop and the integrity of the ozone layer should be valued differently across time.

Natural capital, when healthy, is an appreciating and self-maintaining asset while built capital depreciates and requires active maintenance or it falls apart. This has profound implications for defining sustainability and how assets and investments are treated across time. The benefits that a natural asset provides are garnered across time, most in the distant future, whereas the benefits of built capital, such as a car or levee, are largely delivered in the immediate future, depreciating rapidly, with few or no benefits provided in the distant future. Both built and natural assets are necessary to maintain a high quality of life for people. What is more important now than at any time in the past, when natural capital was abundant, is how we balance investments in natural and built assets. In the past, investments in built capital have substituted for and damaged natural capital. In the future, wiser investments in both natural and built capital should be complementary. For example, wetland expansion protects levees and diversion structures enhance wetland restoration.

Discounting tilts valuation and decision making toward choices that pull the benefits into the present and push costs into the discounted future. High discount rates are biased toward investments that have a high and quick pay off, even though their value may quickly disappear and cause large and long lasting costs. Low discount rates give greater value to future benefits.

For simplicity, we use the four discount rates of 0, 2, 3.5 and 5 percent to underscore the difference in asset value depending on the value given to future benefits. A zero discount rate implies that we in the present hold future flows of ecosystem services to be just as important to people living in the future as the value of those assets are to us today. We limit the time horizon arbitrarily to 100 years for the zero discount rate. This is short sighted. Without limiting the time period the value of natural assets would be infinite, compared to any built capital asset that depreciates. This reflects the true nature of a potentially sustainable flow of value and an asset that falls apart and can only provide a finite flow of value. However, built capital provides important current benefits. A 2-3.5% discount rate implies that people today have a positive time preference so that what remains in the future is less important in meeting current needs than what we have today. It gives more value to the future than the 5% rate or greater, a range that is typically used to value built capital assets or to calculate expected rates of return on monetary investments.

The fact is that how we treat great amounts of value provided for long periods of time into the future is fundamentally an ethical decision; it cannot simply be left to a mathematical calculation based on today's prime interest rate or any other arbitrarily set discount rate.

To conclude this section, calculations of the present value of the flow of ecosystem services show that intact natural systems provide enormous value to society in the short and long term. While we currently need and enjoy the benefits, such as hurricane protection or the supply of drinking water, most of the benefits that healthy natural capital provides, like all renewable resources, will be gained in the future. The cumulative economic benefits from healthy, functioning natural capital across time and generations is tremendous.

At one time, we could assume that all natural capital was basically healthy and functioning well. This is no longer the case. For example, cypress trees cannot grow in saltwater. They will die off if saltwater intrudes through canals or coastal land loss in their area. The economic value that cypress trees provide, such as hurricane protection, will also be lost.

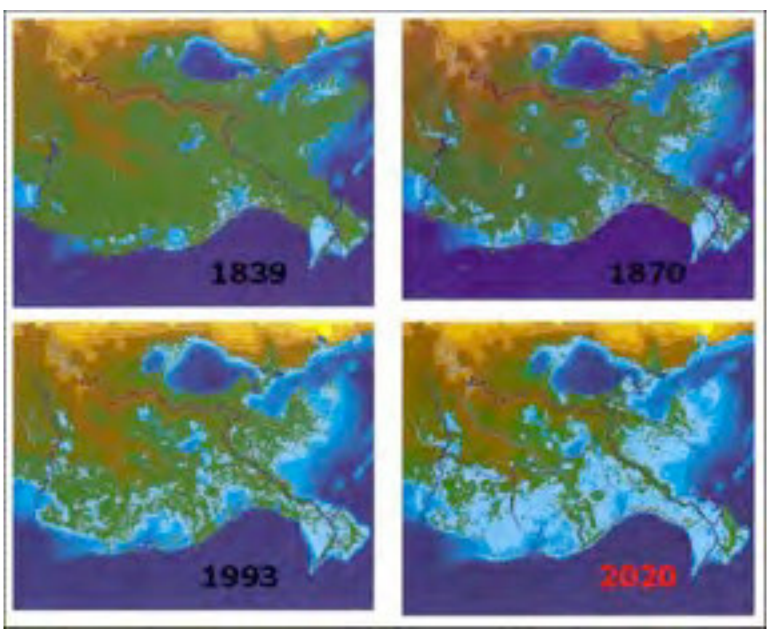
PART III: Lessons from the Delta's Physical Reality

This section examines the changing physical reality of the Mississippi Delta and its importance to the economy. It deals with observed and incontrovertible scientific facts which have very significant economic implications.

A Rapidly Shrinking Delta

After expanding for tens of thousands of years, the Mississippi River Delta started to shrink rapidly eight decades ago, losing over 1.2 million acres of land.[105] This trend continues. An increase in hurricane activity can accelerate this loss.[106] Without renewing the deltaic processes which built and maintained the Mississippi River Delta, land loss acceleration will continue. Land loss carries the loss of critical benefits, including hurricane protection. To understand the economics of the Mississippi Delta, it is important to understand the rates and patterns of land loss from the reduction of sediment and water, hydrological disruption, subsidence, how wetlands and barrier islands buffer against hurricanes, and the full suite of physical changes and their implications. Figure 5 shows the actual and projected loss of coastal wetlands between 1839 and 2020.

Figure 4. Loss of coastal wetlands: 1839 -2020



[105] CPRA, 2007b
[106] Barras et al., 2003

Rates and Patterns of Wetland loss

All deltas grow in some areas and deteriorate in others as the river deposits sediment in one lobe and then shifts sedimentation to another lobe. Sedimentation and wetland plant growth caused the Mississippi River Delta's net land expansion for thousands of years. However, its deterioration in the last 80 years showed a land loss as high as 24,710 acres per year[107] or a total wetland loss of over 1.2 million acres.[108] The land loss rates were highest in the 1960s and 1970s.[109] Current rates of loss were estimated before 2005 at 15,360 acres per year, still a high rate of loss, with a total expected loss of over 328,000 acres in the next 50 years.[110] However, hurricanes Katrina and Rita may have rewritten the estimates of potential land loss. The US Geological Survey stated in 2006:

> "Land transformed to water along the coast and on barrier islands further reduces Louisiana's natural protection from future storms. Louisiana had already lost 1,900 square miles of coastal lands, primarily marshes, from 1932 to 2000. The 217 square miles of potential land loss from the 2005 hurricanes represent 42 % of what scientists had predicted before Hurricanes Katrina and Rita would take place over a 50-year period from 2000 to 2050, even though they had factored storms into their model."

The USGS estimated that 138,000 acres of land were lost to open water due to the 2005 hurricanes.[111] Healthy wetlands are often horizontally compacted by hurricanes only to re-expand after the storm. Similarly, storms can actually benefit wetlands by bringing additional sediment in from the continental shelf. However, if wetlands are unhealthy, as is largely the situation along the coast, hurricanes can physically break them up or bring in saltwater.

As long as the landscape of the Mississippi Delta is deteriorating, the ecological services that are derived from that landscape and are vital to the economy and habitation will continue to deteriorate. A complex array of factors has led to land loss where there should have been a net gain. Human activities primarily caused land loss in the last 80 years.[112]

More than 1.2 million acres of land have been lost to open water with the coast receding 30 miles in some areas.[113] The main causes of this loss are the leveeing of the Mississippi River and the construction of oil, gas and shipping canals which allow saltwater to seep in from the coast thereby increasing salinity and killing freshwater wetlands. This introduced large interior open water areas. Waves attack and wash away land at the expanding land-water interface. Most land loss was in the interior for most part of the 20th century[114] but as wetlands opened up into large lakes, wave erosion has become more damaging.[115] Erosion and stress from the loss of fresh water and sediment inputs, combined with natural land subsidence and sea level rise, cause submergence and increase salinity, killing vegetation.

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[107] Gagliano et al., 1981
[108] Boesch et al., 1994
[109] Baumann & Turner, 1990; Britsch & Dunbar, 1993; National Biological Survey, 1994
[110] Barras et al., 2003
[111] USGS, 2006
[112] Boesch et al., 1994; Boesch et al., 2006; Day et al., 2000
[113] USGS, 2006
[114] Day et al., 2000
[115] Day et al., 2000; Barras et al., 1994

Reduction of Riverine Sediment and Water

The isolation of the Mississippi River from the deltaic plain was accomplished by levees that physically separate the river from the delta and severely damages the delta's health.[116] The Mississippi River is leveed up to its mouth to prevent overbank flooding and crevasse formation. The Old River Control Structure was designed to retain the main channel of the Mississippi River and prevent it from being captured down the Atchafalaya River, a shorter course to the Gulf of Mexico. Because of this, the Mississippi River runs to the edge of the continental shelf; most of the freshwater and sediment load that would have previously nourished the delta is now deposited in deep water. In addition, large quantities of freshwater and nutrients that would have once supplied marshes are lost to the Gulf of Mexico. The large amounts of nitrates that the Mississippi River has been discharging into the Gulf of Mexico has created another problem, a "dead zone" or oxygen-deprived "hypoxic" area which is about the size of New Jersey. Microorganisms use the nitrogen and remove the oxygen from the water. Wetlands are heavy nitrate consuming systems; increases in nitrates promote plant growth and carbon sequestration. Thus wetlands are far better recipients of nutrient-rich water than offshore marine ecosystems. There has also been a reduction of sediment in the river due to the construction of dams and reservoirs in the upper watershed.[117]

Hydrological Disruption of the Delta

There has been pervasive alteration of the Mississippi River Delta's hydrology; it has lost the familiar branching pattern of river deltas. Except for the Atchafalaya River, all the Mississippi River distributaries have been closed. More than 9,000 miles of canals have been dredged for navigation, drainage and logging, but mostly for oil and gas development.[118] These canals form a dense network that effectively changes hydrology and sediment transport in the coastal zone. Figure 6 shows an area, once completely composed of wetlands, crossed with canals and largely converted to open water. Spoil banks associated with canals also reduce the natural sheet flow of water.[119] Deep, straight navigation canals, stretching inland from the Gulf of Mexico to freshwater areas, have caused significant saltwater intrusion and killed vast areas of freshwater wetlands.[120] One of the most notable navigation canals, the Mississippi River Gulf Outlet which was dredged through the Breton Sound Basin in the late 1950s, has an average depth of 30 ft and width of 1,500 ft. Saltwater intrusion caused by MRGO has led to widespread land and freshwater wetland loss.

Katrina's path crossed Breton Sound and areas that were formerly wetlands and are now bounded by spoil banks (dirt accumulated from excavation) created by MRGO. This created a funnel effect for Hurricane Katrina's storm surge, further building it up in height and power and causing the catastrophic levee failure that flooded eastern New Orleans and St. Bernard parish. MRGO resulted in the death of over 10,000 acres of cypress forests in Orleans and St. Bernard Parishes. To prevent future funneling of hurricane storm surges, the U.S. Congress subsequently approved the closure of MRGO upon request by the Louisiana Legislature.

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[116] Day et al. 2000
[117] Kesel, 1989
[118] Day et al., 2000, and Day et al., 2007
[119] Swenson & Turner, 1987
[120] Day et al., 2000 and Day et al., 2007

Cypress forests are highly resistant to being blown down by hurricanes; they reduce storm surge and the wave generation on top of the surge. Had these forests been in place during Hurricane Katrina, the flooding would have been greatly reduced.

Figure 5. Network of Canals in the Mississippi Delta

Source: USGS

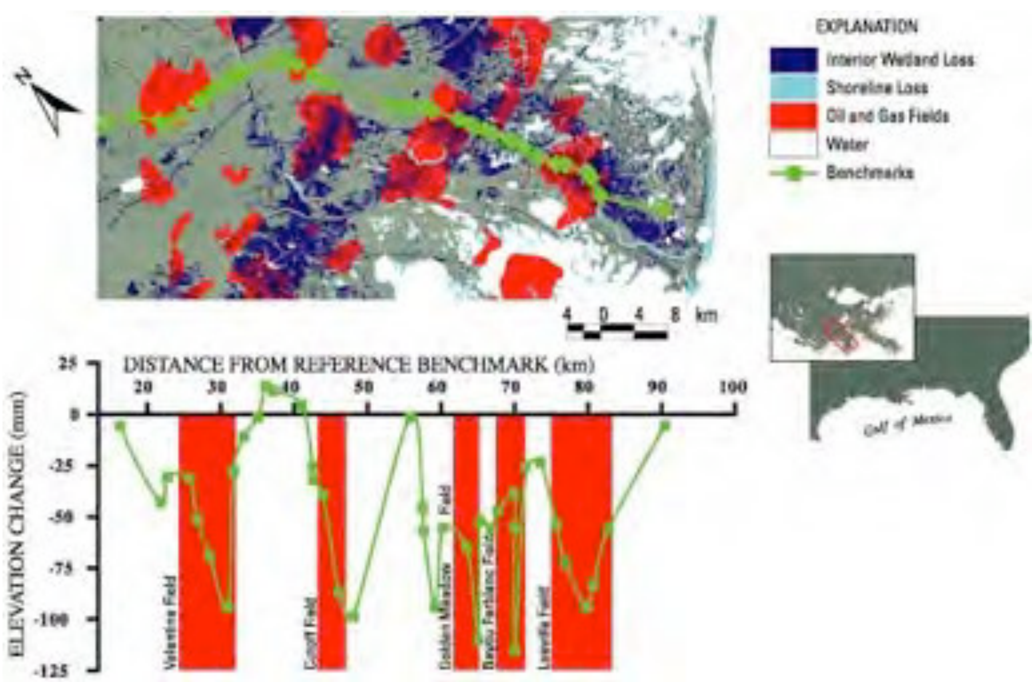
Subsidence

Natural subsidence of river deltas result from the compaction of loosely deposited sediments and dewatering. The Mississippi Delta, like other deltas, constantly subsides, sinking as sediment settles. However, the constant deposit of new sediments for thousands of years brought about a net gain of land and elevation.

Enhanced Subsidence from Oil and Natural Gas Production

Recent evidence from examining large areas of the coast shows that extraction of oil and natural gas increases the rate of land subsidence near oil and gas fields by two to three times, a critical factor contributing to land loss.[121] Morton, a former petroleum geologist who is now with the USGS, found that the highest rates of wetland loss occurred during or just after the period of peak oil and gas production in the 1970s and early 1980s. After much study, Morton concluded that the removal of millions of barrels of oil, trillions of cubic feet of natural gas, and tens of millions of barrels of saline formation water lying with the petroleum deposits caused a drop in subsurface pressure known as regional depressionism. That led nearby underground faults to slip and the land above them to slump downward. Morton does not give a percentage of wetland loss that can be attributed to oil and gas recovery.

Figure 6. Fossil Fuel Extraction and Subsidence



Source: Morton, Buster & Krohn, 2002

[121] Morton, Buster & Krohn, 2002

The upper area of Figure 6 shows the areas of oil and gas fields in a portion of the Mississippi Delta. Oil and gas fields are shown in red while shoreline and wetland loss are in blue. The graph along the transect shows the correspondence between areas of high elevation change (subsidence) and areas where oil and gas have been extracted.

Wetlands and Storm Surge Reduction

Hurricanes gain power over hot, open and deep water; they lose power over coastal barrier islands and wetlands. The Mississippi River Delta wetlands provide hurricane buffering, reducing storm surges. The storm surge of a hurricane is a circulating disk of water that is pulled up by the low pressure of the storm and moves with it. All storms are different but in a perfect storm, the highest point of the storm surge follows the hurricane's eye. As a hurricane approaches shore, the storm surge builds up enormous waves bringing in hundreds of billions of gallons of water.

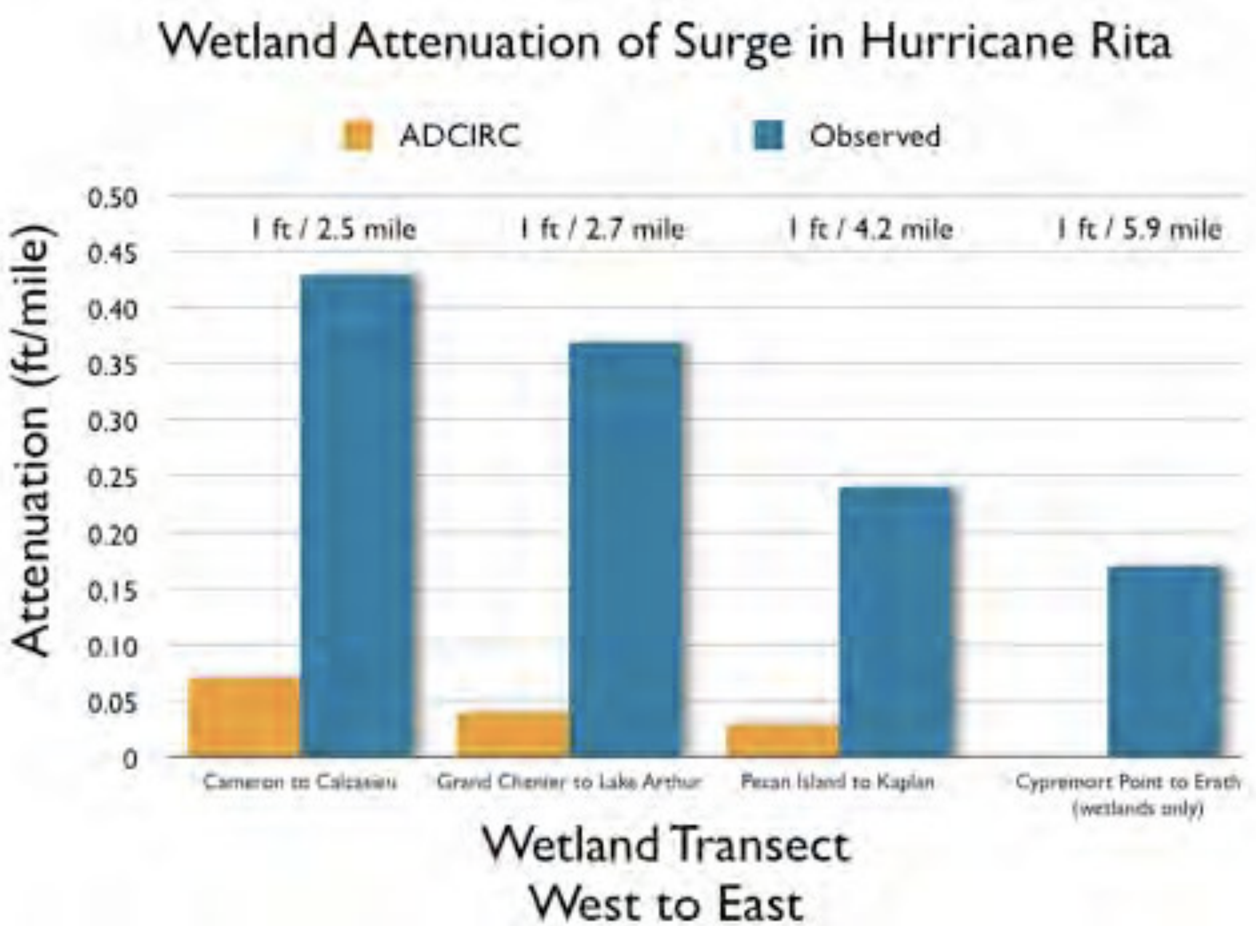
Wetlands reduce storm surge waters. Marshes provide drag and resistance to water movement, reducing the storm's ability to gather storm surge waters. This physically slows the progress of hurricanes and weakens their strength. Wetlands loss results in more open water and less capacity for buffering between land and the Gulf of Mexico where hurricanes develop. The loss of wetlands in the critically important area of the East Orleans land bridge exacerbated the damage that hurricane Katrina wrought because it allowed more storm surge waters to flood into Lake Pontchartrain, causing sea walls in New Orleans to fail and catastrophically flood the city. The receding of areas of the coastline by 20-30 miles since the 1930s removed a significant capacity to diminish the power of hurricanes in Southern Louisiana.

The U.S. Geological Survey (USGS) estimated that wetlands reduce hurricane storm surge by one foot for every 2.5 miles of wetlands. More recent measurements of the effects of wetlands on Hurricane Rita's storm surges indicate that the wetlands may be even more effective at reducing the height of the surges, depending on the storm, by as much as one foot for every 1.4 to 5.9 miles of wetlands. The storm surge models used by the Army Corps of Engineers did not include the wetland buffering function of wetlands.[122] A post-hurricane modeling effort predicted that if all the wetlands near New Orleans had been lost, storm surges from Katrina would have been up to six feet higher, causing far more substantial damage.[123] Other modeling indicates that the loss of barrier islands significantly increases the wave energy hitting the coast, even in mild weather.[124] The Army Corps of Engineers storm surge models do not yet include wetlands as features that reduce storm surge.

Figure 7 shows the expected attenuation (blue) based on modeling which did not include the storm surge weakening effects of wetlands and the observed attenuation (purple) for Hurricane Rita based on the physical measurement of water marks on trees and structures.

[122] Kemp & Mashriqui, 2006; pers com
[123] Working Group for Post-Hurricane Planning for the Louisiana Coast, 2006
[124] Stone, 2004

Figure 7. Kemp and Mashriqui's Wetland Attenuation of the Hurricane Rita Storm Surge



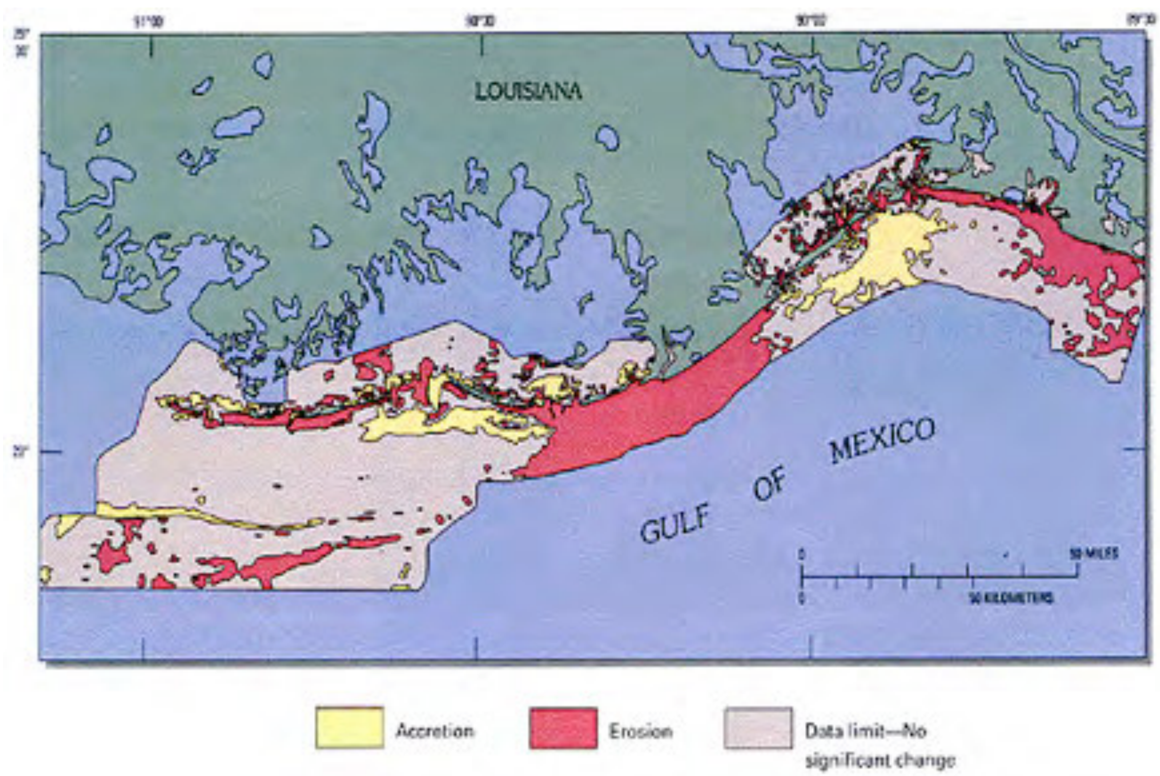
Source: Kemp and Masriqui, 2006

The Chenier Plain, which lies to the west of Mississippi River Deltaic Plain, has also lost wetlands and barrier islands. The Mississippi and the Atchafalaya Rivers influence the Chenier Plain over long periods, but its landforms are different from the Mississippi River Deltaic Plain. Ridge systems made of sand and shells give its coastal landscape a more forested character. No major rivers currently flow through the Chenier Plain. Sediment deposition and land loss mechanisms are also different in this area of coastal Louisiana. Saltwater intrusion from canals and navigation channels has caused the loss of freshwater marsh and forested wetlands. The diminution of the barrier islands have caused increased coastal erosion due to wave energy. Saltwater intrusion also threatens to alter freshwater lakes and reduce water supplies for agriculture. During Hurricane Rita, many levees surrounding freshwater and low salinity impoundments were overtopped by saltwater, leading to widespread death of these marshes and damaging agricultural fields because the saltwater could not retreat or be flushed out by natural processes. Unlike the more populated Deltaic plain, population is more dispersed in the Chenier Plain where agriculture is a mainstay of the local economy.

Wetlands and Barrier Islands

Barrier islands also provide considerable protection against hurricanes and storm surges. They absorb wave energy and provide a direct physical barrier to storm surges, helping protect people and structures from hurricane-generated waves. The Mississippi Coast had barrier islands, like Ship Island, as buffers. These provided important storm protection, reducing storm surges by three feet or more.[125] Construction and management of levees, reservoirs, and flood-control structures have reduced the input of coarse sands that are necessary to maintain barrier islands. As a result, all barrier islands in the delta, and most of the barrier islands in the Gulf of Mexico and along the Eastern seaboard, are deteriorating.[126] The deterioration phase of the barrier island cycle has accelerated while the building phase has stopped. Figure 8 shows the areas where barrier islands have deteriorated (red) and areas of barrier island building continues (yellow).

Figure 8. Areas of Barrier Island Accretion and Deterioration



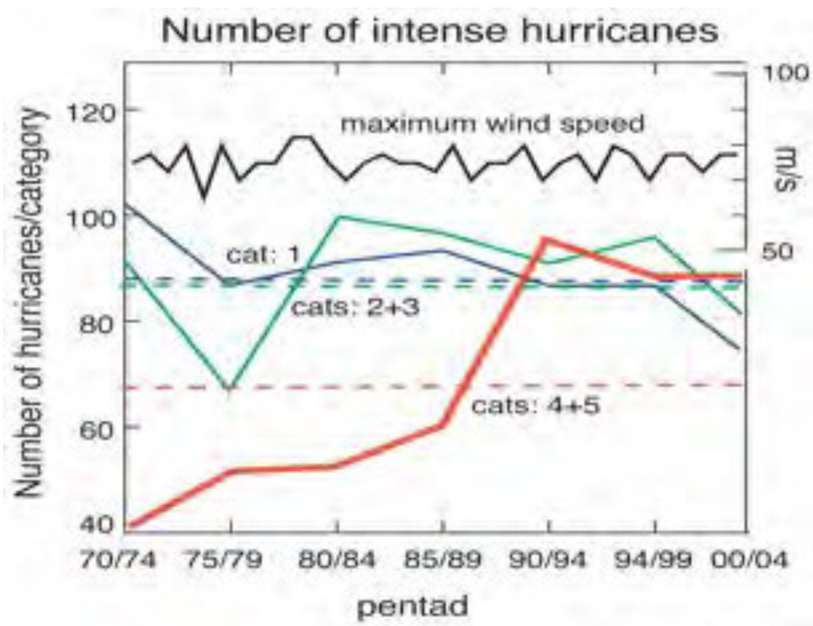
Source: USGS

[125] Farber & Costanza, 1987
[126] Pilkey, 2003

Bigger, Stronger, More Hurricanes

Hurricanes have increased in strength and duration of by 50% in the last 30 years.[127] Maximum wind speeds have increased by 60%, holding about twice the total amount of energy compared to hurricanes more than 30 years ago. The frequency of category 4 and 5 hurricanes, the most powerful and damaging hurricanes, have also risen sharply over the same period. Hurricanes that would have been within category 1-3 are encountering conditions that feed hurricane growth – especially warmer water – and are becoming more powerful category 4-5 hurricanes. There were 171 severe hurricanes 1975-1989, the number rose to 269 in 1990- 2004. Figure 9 from the journal *Science* demonstrates the increase in numbers of more powerful hurricanes.[128]

Figure 9. Increase in Category 4-5 Hurricanes and Reduction in Category 1-3 Hurricanes between 1970 and 2004



Source: Emanuel, 2005

NOAA's findings also show that the intensity of hurricanes has risen since 1980.[129] Hurricanes Katrina, Rita, and Wilma started out as tropical storms – all weaker than category 1 hurricanes when they were in the Atlantic but when they entered the Gulf of Mexico, the hot waters sparked these storms to massive category 5 hurricanes in just a few days.

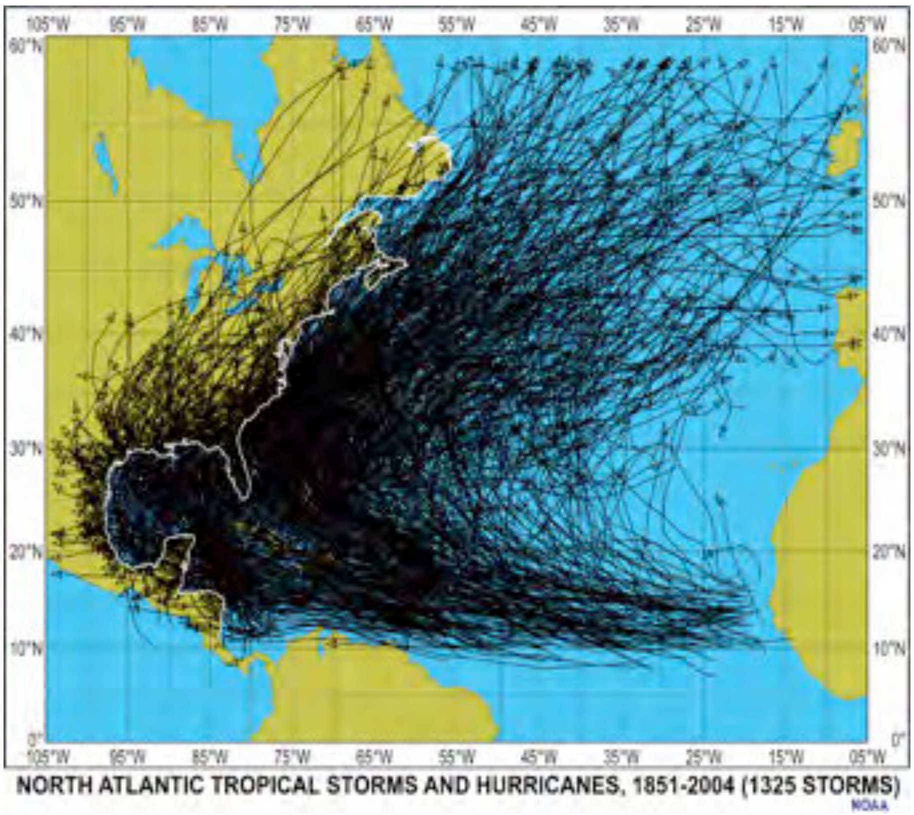
[127] Emanuel, 2005

[128] Webster & Curry, *2005*

[129] Landsea, 2005

More storms will hit the U.S. Figure 10 shows the paths of Atlantic hurricanes in 1851-2004. The trend toward larger and more powerful hurricanes associated with increases in global and oceanic temperatures is a concern for the United States' entire eastern seaboard.

Figure 10. Atlantic Hurricane Paths, 1851-2004



Source: NOAA

The Earth is Warming Up

Tens of thousands of temperature measurements over the last 150 years and geologic, plant and ice data that provide the earth's historical temperatures show that the earth's surface temperature has increased in the last century. Figure 11 shows increases in the earth's surface temperature.[130]

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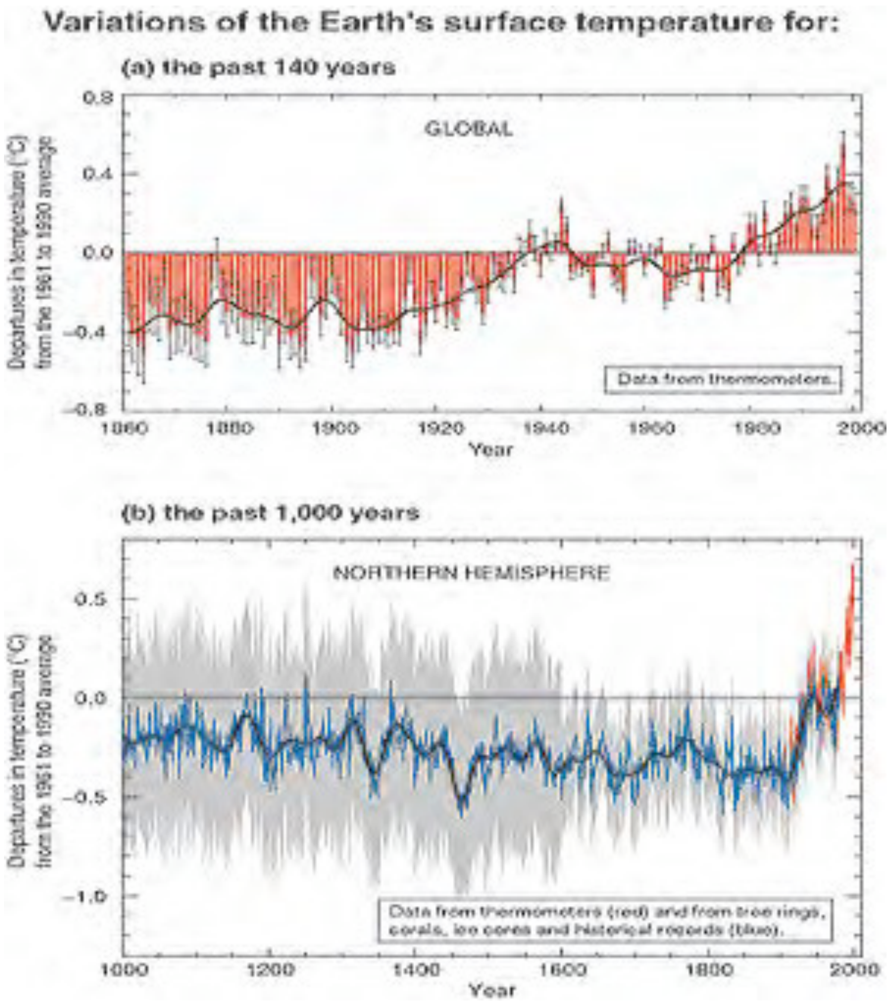
[130] Intergovernmental Panel on Climate Change, 2001

Figure 11. The Earth's Surface Temperature from 1860 to 2000



Source: IPCC, 2001

Two general theories explain this observed increase in temperature. A very small number of scientists, primarily without climate science training, contend that the burning of fossil fuels does not drive the observed increase in the earth's surface temperature. They assert that it is part of a natural cycle and predict that temperatures will again decline at some future time. On the other hand, more than 400 of the world's top climate scientists at the Intergovernmental Panel on Climate Change (IPCC) have ascertained that human activities, including the burning of fossil fuels, partially caused the observed increase in global temperatures.[131]

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[131] IPCC, 2001

IPCC scientists predict that global temperatures will rise by 1-5°C within the 21st century. The increase in temperature will directly affect coastal areas, lead to changes in precipitation, increase the conditions for more powerful hurricanes, and accelerate sea level rise. It is predicted that as the tropics gain more heat, there will be a greater transport of water vapor toward higher latitudes.

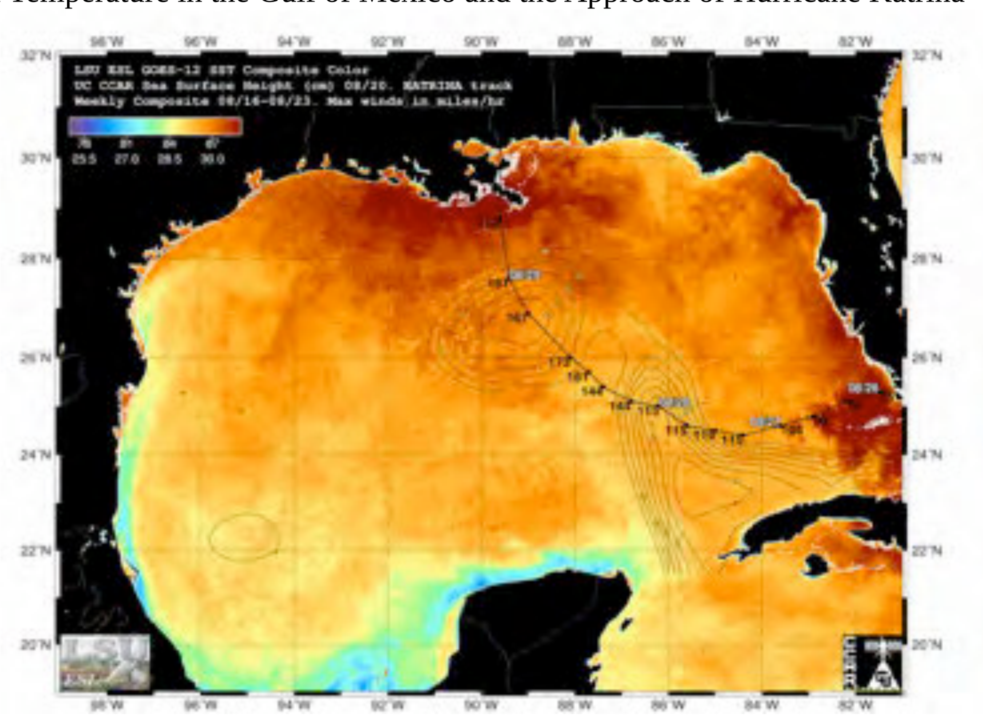
Sea Surface Temperatures

The transfer of heat from marine waters to the atmosphere creates hurricanes. The higher the sea surface temperature, the more quickly hurricanes gain power, the more powerful they become. Rising sea surface temperatures, half a degree globally,[132] are cause for great concern.

The 2005 Hurricane season saw tropical storms Katrina, Rita and Wilma explode from tropical storms into huge category 5 hurricanes upon entering the Gulf of Mexico.

Below is an image provided by the LSU Earth Scan Laboratory that shows the sea surface temperature in the Gulf of Mexico in August 2005. The darkest orange areas correspond to higher sea surface temperatures. The path of Hurricane Katrina and the sea surface height, building of the storm surge is also shown along the black tracking line.

Figure 12. Sea Temperature in the Gulf of Mexico and the Approach of Hurricane Katrina



Source: LSU ESL, 2008

[132] Elperin, 2005; Bart et al, 2007

Sea Level Rise

In low elevation coastlines like Louisiana's and much of the Gulf Coast's, a rise in sea level can profoundly impact wetlands and other ecosystems, particularly with the removal of historic sedimentary sources. Sea level and subsidence combine to increase the effective change in sea level in Mississippi River Delta. For about 3,000 years before 1900, sea levels did not change very much, perhaps rising very slightly. Since 1900 however, global sea levels rose by nearly 20 cm.[133] The IPCC predicted that by the year 2100, the sea level will rise another 11-88 cm.[134] Based on empirical relationships between temperature and sea level rise in the 20th century, Rhanstorf predicted that sea level rise may be one meter or more.[135] Despite these uncertainties, there is no doubt that coastal wetlands in Louisiana will see a high rate of relative sea level rise due to the combination of subsidence and eustatic sea level rise.

The Importance of Levees

The U.S. Army Corps of Engineers (USACE) found that wetlands and swamp forests provide storm buffering that helps protect levees. Heavy waves associated with storm surges force water into the pour structure of levees, weakens them, sometimes to the point of failure. Wetlands break up the wave action of hurricanes so that water rises with less force. Levee specialist Dr. Paul Kemp best described what wetlands do: level out waves so that rising water may overtop levees – not breach them – like water flowing over a bathtub lip, as opposed to a failure, which is like the whole side of the bathtub giving away. Overtopping allows far less water through with far less force, and results in far less damage. While levees are built to protect human safety and economic assets, the 2005 hurricane season showed that levees can also amplify hurricane storm damage.

The Issue with Levees

Tens of billions of dollars were invested in building levees in the Mississippi Delta without considering the land loss this would cause, or the increased vulnerability and economic costs associated with losing vast areas of land, wetlands and barrier islands. Canals for oil and gas drilling were dug, also without concern for the resulting land loss.

Despite having sufficient shipping channels in the Mississippi River, Congress appropriated funds to build and maintain the MRGO canal in the 1960s to shorten the shipping trip from the Gulf of Mexico to New Orleans to 76 miles. Saltwater came up the canal and killed thousands of acres of freshwater wetlands converting them to an open water area shaped like a funnel in St. Bernard Parish southeast of New Orleans.[136] Cypress trees are highly resistant to blow down even with hurricane intensity winds. The sturdy three-dimensional structure of cypress forests reduces surface winds, hurricane storm surge and wave heights on top of the surge. In the wake of Hurricane Katrina, experts and the public decried the "funnel" effect caused by MRGO and the wetland loss it caused which focused and piled up hurricane storm surge waters and demolished protective levees causing much of the destruction in New Orleans and St. Bernard Parish.[137] The USACE initially contested the assertion that the MRGO canal caused the vast loss of wetlands and increased the damage to New Orleans. However, the

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[133] United Nations Environment Programme, 2007
[134] IPCC, 2007
[135] Rahmstorf et al, 2007
[136] Day et al, 2006
[137] Day et al, 2006

evidence that MR-GO both caused wetland destruction and substantially focused and increased the height of Hurricanes Katrina and Rita's storm surge is now widely accepted. The U.S. Congress, upon request of the Louisiana Legislature, directed the USACE to close MRGO. In 2007 the Army Corps settled on a plan and received funding to block the navigation canal. It is now clear that the design of the MRGO shipping canal for the promotion of shipping was at the expense of wetlands "natural capital" and the hurricane protection they provided. This investment in built capital caused greater overall damage than benefit to New Orleans. The substantial cost of closing the canal and restoring the protective wetlands is a good investment.

Levee Successes and Failures

Many levees protecting New Orleans and other areas of the Mississippi Delta performed well while some failed. The 17th Street and London Avenue Canals were lined with levees with seawalls atop, these structures failed because they simply did not meet their required engineering specifications. There is a great deal of research and discussion of these failed structures.[138]

Wetlands protect levees. The photo below shows a section of a levee where Hurricane Katrina storm surge hit from left to right. Notice the base of the photo where a wetland buffers the levee. Water overtopped the levee, flowed over it, scoured the other side, but did not breach or destroy the levee. Wetlands broke the wave action associated with the hurricane storm surge. This protected the levee and seawall from the pounding wave action of the storm surge; the storm surge rose more gently, like water filling up a bathtub. The structure was overtopped, but not destroyed. The top of the photo shows that where there was no wetland buffer, storm surge waves were unbroken. The full wave action pounded the levee and floodwall structure. The levee was breached, allowing a torrent of floodwaters to enter A levee breach lets in the full depth of floodwaters, causing catastrophic damage, like punching a large hole in the side of a bathtub. Where levees are overtopped, they allow some water to flow while yet holding most of the floodwaters back until the storm surge recedes, causing far less flooding and far less damage.

Figure 13. Levee Damage after Hurricane Katrina

Photo Credit: G. Kemp

[138] Louisiana Department of Transportation, 2007

Levees Can Amplify Hurricane Storm Surge and Damage

It now appears that the 29-foot storm surge from Hurricane Katrina that devastated the Mississippi coastline was partially created by levees along the Mississippi River. Hurricane storm surges move in a rotation around the eye of the storm. A northward arm of the storm surge struck the coastline directly, while a southern moving arm of the storm surge was reflected off the Mississippi River Levee and back toward the Mississippi coastline, creating an additive effect.

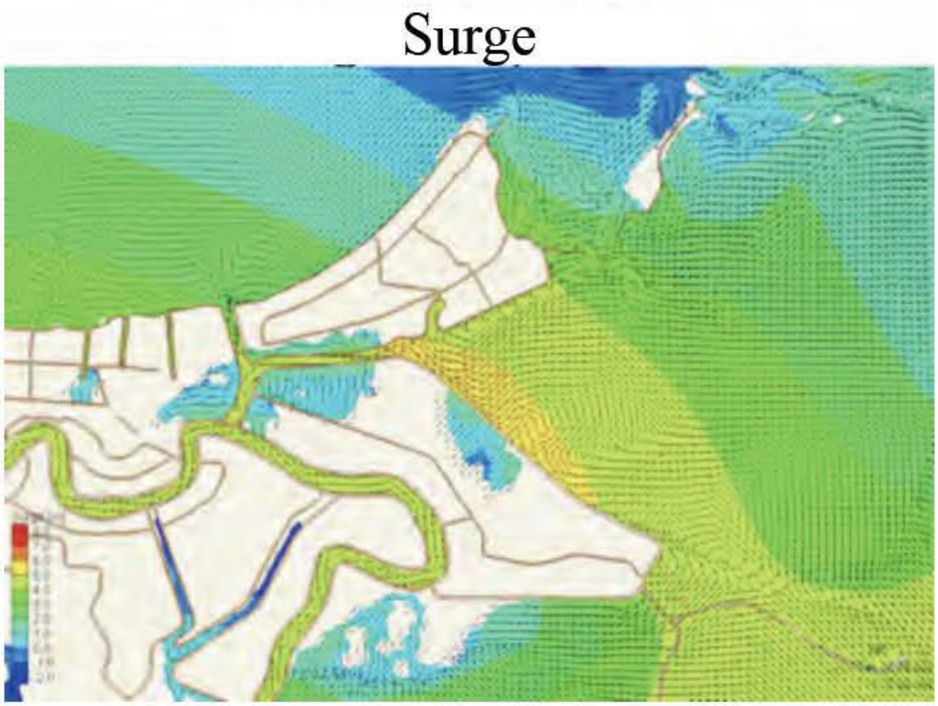
The levees that maintain the MRGO Canal on the northeast boundary of St. Bernard Parish and the shipping canal to the south of eastern Orleans Parish created a v-shaped funnel, leading storm surge waters directly into New Orleans. As storm surge waters moved west from the path of Katrina into this “V” created by the canals, the funneling effect increasingly confined the storm surge waters as they approached New Orleans, increasing the height of the storm surge and demolishing the levees that protected the southern part of the city.

Figure 14. The “Funnel” Exposing New Orleans to Increased Storm Surge Damage

Source: Dr. Paul Kemp, 2006

Dr. Hassan Mashriqui modeled the storm surge of hurricane Katrina showing the amplification of the storm surge in the funnel. This is just a “snap shot” of one point in time as the storm surge built up then overtopped or breached levees in St. Bernard Parish, East New Orleans, and New Orleans.

Figure 15. Katrina Storm Surge "Snap Shot"



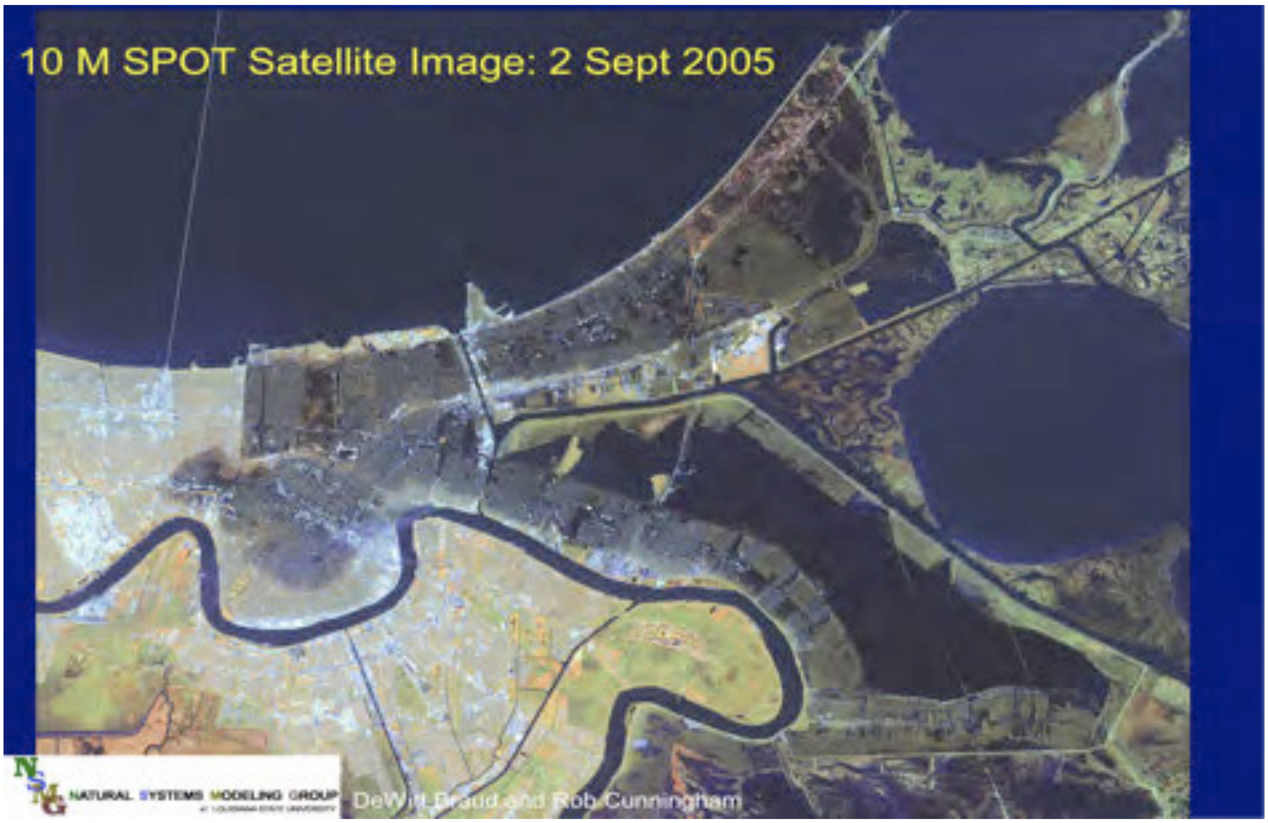
Source: Dr. Hassan Mashriqui of Louisiana State University, 2006

Figure 16. Storm Surge of Hurricane Katrina Amplified by Levees in the "Funnel"

Picture taken by an automatic camera located at an electrical generating facility on the Gulf Intracoastal Waterway (GIWW) where the Route I-510 bridge crosses the GIWW. This is close to where the Mississippi River Gulf Outlet (MRGO) enters the GIWW. The shot clearly shows the storm surge, estimated to be 5.5-6m (18-20 ft.) in height.

An automatic camera from an electric-generating plant at the Interstate Bridge on Parish Road caught an image of the massive storm surge likely amplified by this funnel effect close to the end of the funnel. The levees' constricting effect amplified the storm surge to a height of 18-20 feet.

Figure 17. Flood Caused by the Breaching of New Orleans' Protective Levees



Source: National Systems Modeling Group, 2006

The Decline of Oil and Natural Gas Reserves and Production

One of the most profound global and local physical changes affecting energy prices and industrial society is the global decline in oil reserves. This has an important bearing on wetland restoration decisions. Some delta restoration and levee options are more energy intensive than others. Allowing the Mississippi River to move vast amounts of sediment and water is far less expensive than constructing levees and pumping sediment. With rising fossil fuel prices, restoration options that utilize the river's energy will continue to be less expensive than extensive levee works and other energy intensive options. Another critical fact to consider in levee/delta restoration is the depletion of oil and gas reserves in Louisiana, the U.S. and the world. Vast, easily accessible fossil fuel reserves have been depleted; cheap oil will not be available in the future.

In the past, if world demand for oil rose, supply could be easily expanded. This is no longer true today. Because the world's oil supply has become inelastic (the supply curve is close to vertical, and supply does not readily expand in response to increases in price), when demand is high, prices rise dramatically. When demand falls, prices fall dramatically. This was borne out in just the few months between the high demand period of the summer of 2008, where oil prices surpassed $140/barrel, and the fall of 2008 when global recession depressed demand and prices fell to less than $40/barrel.

U.S. oil production peaked in the early 1970s. Except for a brief smaller peak in production from Alaska's Prudhoe Bay, U.S. oil production has declined steadily. According to the Louisiana Department of Mineral Resources, "overall crude oil production in the state has fallen considerably from peak production levels attained in the mid 1960s (North Louisiana) to early 1970s (offshore and South Louisiana). Today, crude oil production is 17% of its 1965 peak production in North Louisiana, 12% of its 1970 peak in South Louisiana, and 12% of its 1972 peak in offshore Louisiana. Relative to their respective peaks, crude oil production in North Louisiana has experienced an annual average decline of almost 5%, with South Louisiana and offshore Louisiana each seeing a 6% average decrease per year."[139] Louisiana's oil production has been in decline for over 35 years and continues to decline.

Natural gas production in Louisiana has also peaked and is now declining. Offshore production will peak. Oil and gas have been a major part of Louisiana's economy for decades. With the decline oil and gas reserves, these non-renewable resources may play a smaller role in the state's economy. Production is expected to trail off considerably in another 10 years. These declines in production are critical; they signal a need for a post-oil economic strategy for the state and nation. Renewable resources will need to play a larger role in the future. As global oil reserves are depleted, oil prices as well as transportation and construction costs will rise in the long run despite temporary declines in price associated with demand reductions, as in the current recession. Energy prices have a dramatic effect on the cost of energy intensive projects, such as levees, and improve the overall economics of restoration projects, such as diversions, which utilize the Mississippi River's energy to transport water and sediment.

It is wise to now invest in large diversions to restore the Mississippi Delta. Diversions have upfront costs and provide employment opportunities in construction and very low operating costs. The upfront construction costs of diversions will most likely be less today than they will be in the future while the benefits will accrue in the future as oil and gas revenues decline. Energy intensive restoration techniques, such as piping dredged sediments, are likely to become less viable in the future.

Summary: Facing Physical Realities

Economies depend on ecosystems, natural resources and stable landscapes. Science has clearly shown that physical processes are driving larger hurricanes and destroying wetlands and barrier islands. The loss of land is reducing the valuable wetland and barrier island storm buffering endangering economic assets and people. If these trends continue unabated, viable economies may decline in many parts of the Mississippi Delta. These facts lay the groundwork for a better economic understanding of the Mississippi Delta and the profound

[139] Dismukes et. al, 2004

implications of a very physically dynamic system for people, local governments, infrastructure, housing and industries, including the oil and gas industry.

These are measured scientific observations and physical facts, not theory:

- Hurricanes are getting larger, more destructive, and more costly.
- Land, wetlands and barrier islands (horizontal levees) reduce hurricane impact.
- Land, wetlands and barrier islands are being lost and converted to open water.
- Hurricanes gain power over deep, warm, open water.
- Some levee configurations magnify storm surge and storm surge damage.
- The Mississippi River Delta is subsiding (sinking).
- Land expands where water and sediment are provided.
- Sea level is rising.
- Global atmospheric and ocean temperatures, including the Gulf of Mexico, are rising.
- Oil and gas reserves are declining in Louisiana, the U.S. and the world. Energy intensive options will become more expensive and less feasible.

The physical reality of these dynamic changes holds tremendous economic implications for the United States, the Mississippi River Delta and the states along the Gulf of Mexico and Atlantic coastline. Part IV of this study examines three scenarios and their economic implications.

PART IV: Restoration Scenarios

This section examines three management scenarios of the Mississippi Delta and the economic implications of each scenario in 100 years. The values of ecosystem services provided by each scenario are calculated. Estimating the cost of each scenario is outside the scope of this study but should be examined.

The ecosystems of the Mississippi Delta provide benefits ranging from $330 billion to $1.3 trillion, contributing to the national economy and the quality of life. How much, where, and by whom should investments in restoration and levees be made? What should the balance be? These are critical questions arise with radically different alternatives being considered.

One thing is certain. The continued degradation of the Mississippi River Delta threatens public safety, economic productivity and ecosystem services. The damage to oil production, pipelines and refineries has national economic implications. Without wetland expansion hurricane damage will result in higher prices for gasoline, jet fuel, diesel, fuel oil and natural gas for the entire U.S. as it did after Hurricanes Katrina, Rita, Gustav and Ike. Better management of the Mississippi Delta is critical to the U.S.

Part 1 of this study introduced a “new view on value,” and the critically important role of natural capital for the economy of the Mississippi River Delta. Part II provided a valuation of 11 ecosystem services and net present value calculations establishing that the delta is an enormously valuable natural capital asset. Part III of this study shows how the dramatic, dynamic physical changes affecting the Mississippi River Delta have profound economic implications. This section examines three scenarios for the Mississippi Delta: continued delta deterioration and land loss, a modest investment in delta restoration, and a more aggressive investment in the restoration of the Mississippi River and the delta.

Three Scenarios

Hurricanes Katrina, Rita, Gustav and Ike renewed wake-up calls for the large-scale physical and economic changes that have been taking place in the Mississippi Delta. Greater efforts need to be exerted toward determining how to best respond to the physical, economic and social dynamics of a changing delta.

The three scenarios considered here are: 1) do nothing new 2) hold the line and 3) restore the delta. These scenarios actually represent the three general suites of approaches to the problem of land loss in the Mississippi Delta. Each has a set of different possible actions, investments in built and natural infrastructure, and economic and social ramifications. This is not intended to be an exact analysis but a broad examination of three overarching approaches. It is intended to shed light on the set of alternatives currently being considered for the delta and to offer far more economically productive options.

The "do nothing new" scenario assumes the continuation of the past management of the Mississippi River. Large investments in levees and reconstruction of hurricane-damaged structures to keep water and sediment flowing off the continental shelf pertain to a management regime that has lead to the loss of 1.2 million acres in the delta. The Mississippi River will remain, as it does today, separated from the Mississippi Delta resulting in greater wetland losses, greater losses of ecosystem services, and the increased exposure of towns and cities to hurricanes.

This scenario is based on the U.S. Geological Society's estimate of wetlands loss of 328,000 acres in the next 50 years.[140] It is assumed that an additional 272,000 acres will be lost as the impact of subsidence and sea level rise intensify in the next 50 years. This may be a very conservative estimate since 42% of the predicted land loss for the next 50 years has already occurred with the loss of 138,000 acres from Hurricanes Katrina and Rita. Based on the pattern of land loss in the last 80 years and on the experience of hurricanes Katrina and Rita, wetland loss is not linear. Hurricanes may also abruptly increase the loss of wetlands where they are not healthy. Initially, high wetland loss rates decline as there are fewer wetlands to lose. Thus, the shape of the wetland loss curve adopted is concave, reflecting the history and nature of wetland loss.

The "hold the line" scenario carries the entire set of issues on coastal restoration presently considered by the U.S. Army Corps of Engineers. There are many potential project combinations to try to achieve this goal. If successful, it will result in no net land loss. The delta will lose land in some areas and gain land elsewhere with overall land coverage remaining the same. Although this scenario significantly improves on the first scenario with the use of some small diversions, it does not bring a fundamental management shift. The Mississippi River will remain disconnected to the delta and most of its water and sediment of the will continue to flow off the continental shelf.

[140] U.S. Geological Survey, 2004

Questions persist whether this scenario can be achieved. Deltas involve large landscape processes that create and maintain them. They are either restored so that they shift toward sediment/water/land building balance or are not restored resulting in land loss. This analysis assumes the viability of holding the line. If the deltaic processes are not restored at the scale required, the Mississippi River Delta will continue to shrink and fall apart. Trying to hold the line through a combination of small projects or energy-intensive sediment pumping can be considerably costlier than a fundamental reworking of the system with large diversions that, once in place, move far more water and sediment per dollar spent.

The “sustainable restoration” scenario – rejoining the river and the delta – brings a fundamental shift in policy and action. This scenario includes large diversions and crevasse structures in the levees of the Mississippi River that can be opened, particularly during flood periods when the flow and sediment loads are high. This moves water and sediment into large wetland and open water areas to restore wetlands. Other restoration ideas also need to be considered, such as a structure in the bottom of the river to force bottom sediment up and into diversion channels when desired. Diversion and crevasse structures can always be closed to accommodate shipping or low water periods.

Most of the water and sediment would be taken out of the Mississippi River during peak flows when sediment and water levels are highest, thereby providing the greatest restoration value and the least conflict with navigation. During periods of low flow, the quantity of water diversion would be scaled back to allow continued navigation.

Restoration planning over longer periods and inclusive of a greater area of the Mississippi Basin dramatically improves results. Much of the larger grain sediment from the Mississippi Basin has been trapped behind dams for 80 years. These dams will be filled with sediment in coming decades. Upper Mississippi River dams will require decommissioning or sediments flushing in the next 100 years. If developed as part of a Mississippi River basin plan, this heavier sediment can be provided through a controlled release, adding very substantially to the quality and quantity of the river’s sediment load and capacity for coastal restoration. Barrier Islands throughout the Atlantic and Gulf Coast have been deprived of sand from upstream rivers. Under this scenario, upper basin sediment will be managed to increase downstream benefits. Another option in the short term, prior to further reductions in oil production and increases in price, sediments can be pumped to promote rapid wetland recovery and expansion.

Like the “hold the line” scenario, there are many combinations of potential projects that can achieve this goal. Identifying the suite of projects to be implemented involves the use of spatially specific modeling which can account for multiple benefits, such as storm protection, land building, coastal economic recovery potential, recreation and carbon sequestration to set up and test different suites of river reconnection projects.

This excludes the cost of a sustainable restoration for lack of full project identification that can be used as basis of costs. Like the other two scenarios, this also needs to include the returns in avoided costs and a suite of sustainable and valuable economic goods and services gained. Trapping the water and sediment of the Mississippi River will bring significant co-benefits, including a reduction in the “dead zone” hypoxic area in the

Gulf of Mexico, as the nitrogen is trapped and utilized by wetland plants in the delta. These co-benefits are not included in this preliminary analysis.

Modeling has not included the eventual release of currently impounded sediments. Thus, there is no clear estimate of land restoration under a scenario that utilizes currently- impounded sediments, some sediment pumping, and release of as much of the water and sediment of the river as possible. The sustainable restoration scenario assumes that with the release of large sediment loads, wetland recovery and growth rates, increased release of silt and sand in coming decades, diversions and some sediment pumping, 500,000 acres of wetlands can be created or restored in the next 100 years. Data and modeling are not yet available for accuracy in estimating the acreage of wetlands restored from a long term, coast-wide restoration. This is intended to promote a wider analysis and the consideration of the general suite of restoration options and to recognize that economic analysis, which includes ecosystem services supports the implementation of restoration projects now.

It is important to consider this scenario. Academics, NGOs, businesses and coastal communities have been calling for restoration on a scale that would reestablish deltaic processes and result in a net gain in land in the long run. With the addition of wetlands, the ecosystem services these lands provide, especially hurricane buffering, would expand over time.

Costs and Scenario Details

No option is cheap. Under the “no action” scenario, the deterioration of the delta will continue along with the loss of nature’s services and increasing damages to communities and economic assets. It will ensure a costly retreat of people and economic productivity. The “hold the line” scenario requires an unknown set of smaller projects to stop land loss without restoring the functions of the Mississippi River Delta. The third scenario entails large projects that reconnect the sediment, water and energy of the Mississippi River with the delta. All these options entail significant expenditures. Further analysis would refine the costs, benefits and net rate of return on restoration investments.

These three scenarios are meant to spur further research rather than present a detailed modeling effort. Economic analysis of changes in wetland values relies on the accuracy of the physical changes in each wetland type. This analysis is of three very broad scenarios with coarse physical estimates, thus the economic analysis is also coarse. Since the exact changes in wetland type for each scenario are unknown, single average values for wetland values were used. As the physical analysis of restoration alternatives becomes more robust, more refined economic analysis based on ecosystem-specific values can be produced.

The restoration of wetlands largely involves the conversion of estuarine open water to wetlands with a movement of the salt gradient toward the coast and conversion of salt marsh to brackish marsh, brackish to intermediate, and intermediate to fresh marsh.

The inland movement of the salt gradient and conversion of wetlands into estuarine open water results in wetland loss. The low value of estuarine wetlands was subtracted from the average low value per acre per year for all wetland types, excluding the highest wetland value for forested wetlands to derive a net loss or gain value of $4,515/acre with the conversion of wetlands to open water or open water to wetlands for the three scenarios.

- Land loss in the “do nothing new” scenario in 100 years is set at twice what the U.S. Geological Survey predicts to occur over the next 50 years. This adds up to a loss of 500,000 acres in the next 100 years.
- The “hold the line” scenario assumes there is no net gain or loss of land in the next 100 years.
- The “sustainable restoration” scenario assumes that with large-scale restoration over a 100-year period, roughly 40% of the wetlands lost in the last 80 years would be restored totaling 500,000 acres. This is a speculative scenario if short-term sediment pumping, long-term river restoration and release of basin sediments were secured.

Each scenario translates into a net loss or gain of ecosystem service values in the next 100 years. A larger time horizon would accentuate the differences between the scenarios. The net present value of benefits from ecosystem services, not total project costs, for each scenario was calculated. Cost projections for the various restoration scenarios are not included because they are difficult to ascertain without actual project identification.

The calculation of net present value of land loss or land gain depends on the discount rate chosen, which reflects how value received in the future is counted in the present. A lower discount rate implies giving greater weight to the benefits that storm protection, fisheries and other ecosystem services provide to people in the future. A vast majority of benefits from renewable resources are provided in the future. Healthy natural capital does not depreciate. Lower discount rates for natural capital restoration are justified – as opposed to built capital that depreciates. The choice of a discount rate is arbitrary. At times the US Prime rate is used as a marker. As of February 2009, the commercial bank prime rate of interest was 3.25%. In February 2009, the U.S. Federal Reserve Bank Open Market Committee in continued response to the financial crisis retained the remarkable fed funds rate of 0-0.25%[141]. This is the interest rate that banks lend cash to each other overnight in the Federal Funds Market.

Table 9 shows the Present Value of the conversion of wetlands and open water. It does not include the total cost of implementing each of the scenarios. This is a comparison of an estimated net gain or loss in ecosystem services associated with each scenario.

Table 9. Three Scenarios of Present Value of Wetland Ecosystem Services for 100 years (in billions, 2007 dollars).

Present Value of Scenario				
Scenario	**Discount Rate 0%**	**Discount Rate 2%**	**Discount Rate 3.5%**	**Discount Rate 5%**
Do Nothing New	-190	-72	-41	-26
Army Corps No Net Loss	0	0	0	0
Sustainable Restoration	132	41	21	12

[141] U.S. Federal Reserve Bank, 2009

Depending on the discount rate chosen, the “no action” scenario will result in losses of $26-190 billion in ecosystem services alone. This does not include losses such as the costs of future damage by hurricanes, retreat of economic infrastructure, or loss of life. Losing over 500,000 acres of wetlands would leave New Orleans and other coastal cities far more exposed to hurricanes. Hurricane Katrina showed that a single event can cause $200 billion in damage.

The “no change” scenario has no net increase or decrease in values. This scenario would avoid the negative costs associated with the “no action” scenario, but would not increase storm protection or other ecosystem services provided at higher levels in the past.

The “sustainable restoration” scenario will add over 500,000 acres of wetlands in a century and significantly add to the hurricane protection of New Orleans and other cities and communities on the Mississippi River Delta. Because this is a building process, the benefits will increase dramatically in the future. The benefits from the net gain in wetland area will be between $12-132 billion. In addition, the costs associated with the “no action” option will be avoided.

Table 10 shows the total present value of benefits in scenario 3, the sum of avoided costs associated with the “do nothing new” option, and the gains from the increase in additional wetlands.

Table 10. Total Present Value for Scenario 3, Avoided Losses and Gains Realized in $ Billions

Major Restoration Scenario	**PV 0% Discount Rate**	**PV 2% Discount Rate**	**PV 3.5% Discount Rate**	**PV 5% Discount Rate**
Total PV Avoided Costs and Direct Gains	322	113	62	38

Scenario 3 increases the area of land and avoids the costs associated with the current path of land loss. This provides a net benefit of $322 billion with a zero discount rate if future benefits to people are counted equally as benefits to people in the present or $38 billion at a 5% discount rate if renewable benefits provided in the future are rather steeply discounted and deemed as having little value. The US Prime Rate of Interest as of February 1, 2009 was 3.25%. The figure conservatively adopted here is $62 billion at a 3.5% discount rate. Not included in this analysis, these wetlands would also provide greater protection for any built structure, including levees. Adoption of a 2% discount rate, that is recognizing the greater benefits of restoration in the future, would show over $100 billion in benefits.

Restoration of the coastline would reduce levee maintenance and reconstruction costs substantially. A larger skirt of wetlands around the Mississippi Delta would provide greater hurricane buffering. This alone could reduce future damage to cities like New Orleans by tens or hundreds of billions of dollars.

Even though many of the most important cost and benefit outcomes of these scenarios are beyond the scope of this study or not easily expressed in dollar value (human safety, future FEMA relief costs or community stability), the direction of the outcomes for each scenario is clear. For this reason, we present two tables that examine the likely outcomes of each scenario rated simply "Up, Down, or Same".

Table 11 shows the direction of the cost/damage outcomes for each scenario. The list of costs and damages is not comprehensive. It includes: loss of life, displacement of people, loss of infrastructure, storm-associated national energy price increase, insurance costs, FEMA and other relief costs, storm damage costs, post storm litigation, loss of the coastal economy, and area of the hypoxic dead zone in the Gulf of Mexico.

Table 11. Likely Cost or Damage and Scenario Outcomes

Cost/Damage	**Scenario Outcomes**		
	"Do Nothing New"	**Hold the Line**	**Sustainable Restoration**
Loss of life	Up Greatly	Same	Down
Dislocation of People	Up Greatly	Same	Down
Loss of infrastructure	UP Greatly	Up	Down
Storm Associated Energy Price Rises	Up Greatly	Up	Down
Insurance costs	Up Greatly	Up	Down
FEMA and relief costs	Up Greatly	Same	Down
Storm Damage Costs	Up Greatly	Up	Down
Post Storm Litigation	Up Greatly	Up	Down
Loss of Coastal Economy	Up Greatly	Up	Down
Area of Dead Zone	Up	Same	Down

Table 12 shows the direction of the benefit outcomes for each scenario. The list of costs and damages is not comprehensive. It includes: coastal stability, land building, storm protection, community stability, protection of levees, protection of energy infrastructure, wetland expansion, economic development potential, food, furs and fiber, wildlife habitat, water quality, carbon sequestration, waste treatment, recreation, aesthetic value, people's sense of security and national pride.

Table 12. Likely Benefit Scenario Outcomes

Benefit	"Do Nothing New"	Hold the Line	Sustainable Restoration
Coastal Stability	Down	Same	Up
Land building	Down	Same	Up
Storm Protection	Down	Same	Up
Community Stability	Down	Same	Up
Protection of Levees	Down	Same	Up
Protection of Energy Infrastructure	Down	Down	Up
Wetland Expansion	Down	Same	Up
Coastal Economic Development Potential	Down	Same	Up
Food, Furs, Fiber	Down	Same	Up
Wildlife Habitat	Down	Same	Up
Water Quality	Down	Down	Up
Carbon Sequestration	Down	Same	Up
Waste Treatment	Down	Same	Up
Recreation	Down	Down	Up
Aesthetic Value	Down	Same	Up
People's Sense of Security	Down	Down	Up
National Pride	Down	Same	Up

Tables 11 and 12 provide the direction of impact of each scenario for each outcome area. The "do nothing new" scenario will increase costs in virtually every category over current costs.

The "hold the line" scenario stabilizes some of the outcomes. If the goal of no net land loss is attained, overall coastal stability and land building will not deteriorate further but it will not experience a net advance either. Stopping land loss will not stop the deterioration of water quality but it will likely result in a decline in the protection of energy infrastructure because land building in a hold the line scenario will be focused where it protects inhabited areas and land loss will likely continue to take place where important energy infrastructure exists more distant from population centers.

The "sustainable restoration" scenario provides greater benefits and fewer costs by providing a net gain in land and large diversions that enable controlled distribution of sediment and water across the Mississippi Delta. Overall, sediment pumping, barrier island reconstruction and other restoration methods all increase land and the suite of benefits they bring. The dollar calculation of benefits based on a few ecosystem services and a cursory examination of the direction of benefits for the three options clearly show that the "sustainable restoration" option provides the greatest benefits and least costs. Neither the full costs nor full benefits of the projects are included. For example, the "do nothing" option may entail the outstandingly costly relocation of the people and assets of New Orleans. The sustainable restoration option may ensure the viability of New Orleans and secure vast assets and less disruption for many people.

One of the most persistent political tragedies has been that while the scientists, academics, state officials and citizens have emphasized the importance of reconnecting the Mississippi River to the delta as proposed in the Louisiana Coastal Protection Restoration Draft Technical Report, this option has not been considered by decision makers, such as the Army Corps of Engineers, as an option for coastal restoration.[142] This scenario analysis indicates that investing in sustainable restoration at a larger scale is the best approach. It provides the greatest benefits under any discount rate. The sustainable restoration scenario provides far greater and more comprehensive hurricane protection and provides for greater economic productivity in the Mississippi Delta. The sustainable restoration option to reconnect the Mississippi River to the delta should be the basis for restoration investment in the Mississippi Delta.

The many different combinations of delta and levee restoration each produce a different land restoration or deterioration scenario. Human safety, the impact on economic assets and the overall dynamics and sustainability of the Mississippi River Delta are critical to determining which levee/coastal restoration option will provide the greatest public safety, protection of economic assets (including natural assets) and coastal restoration value. The current levee designs are not integrated with wetland restoration models. None of the economic analyses fully include the value of ecosystem services. Including ecosystem services and their value would provide a better understanding of the value of public investments in restoration.

The persistent pursuit of restoration projects that are too small compared to the scale of the Mississippi Delta and its land loss is another notable flaw in the current management. The Coastal Protection and Restoration Authority of Louisiana has recognized this and said that “Creating a sustainable deltaic system requires that we reestablish the processes that originally created the landscape.” The plan specifically recommends “building very large diversions that will use the majority of the river’s sediment and fresh water to both create new delta lobes and nourish existing wetlands.”[143] The report does not identify the locations and size of these diversions, but has produced a list of projects that comprise a partial coastal restoration plan. This was an important step forward but it needs the set of projects for moving very large amounts of water and sediment out of the Mississippi River and into the deltaic plain.

The scientific and coastal communities as well as the State of Louisiana are calling for far larger diversion projects that will significantly restore the Mississippi Delta’s natural sediment regime and provide a net increase in and more enduring maintenance of existing wetlands. The natural functioning of the delta must be a guide to restoration. Before the levees became widespread, there were many crevasses, often as large as or larger than the Bonnet Carre spillway. This scale of diversion must be considered especially with the increasing sea level rise. A primary concern has been maintaining navigation channels however this is relatively easily addressed by constructing locks or using peak flow periods which are the natural sediment load land building potential is greatest and where utilization of diversions does not interfere with navigation.

Larger restoration projects may be the only hope for a maintaining a sustainable landscape and economy as well as the long-term sustainability of ports and cities like New Orleans.

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[142] Army Corps of Engineers, 2008
[143] Executive Summary, CPRA, 2007a

CONCLUSIONS

Mississippi River Delta Ecosystems provide economically valuable services, including hurricane storm protection, water supply, climate stability, food, furs, waste treatment, wildlife habitat, recreation and other benefits. These services are valued at $12-47 billion/year.

This flow of annual benefits provides a vast amount of value to people across time. A “natural capital asset value” can be established from these annual benefits. The present value of the benefits from these ecosystem goods and services provided by the Mississippi Delta, analogous to an asset value, is worth at least $330 billion to $1.3 trillion.

Wetlands – a product of Mississippi River deltaic processes including freshwater, saltwater, estuaries/tidal bays and cypress swamps – account for more than 90% of the Mississippi Delta’s estimated total value of ecosystem services.

These benefits are derived from “natural capital” which is self-maintaining and lasts for a long time; it is fundamentally different from “built capital” which depreciates quickly and requires capital and maintenance costs.

In the past, our natural capital was taken for granted. Although natural systems provide economic goods and services such as fish and hurricane protection, they have not been valued as economic assets and were excluded from economic analysis and investment decisions.

Large-scale physical changes are affecting the Mississippi River Delta. In the last 30 years, oil and energy costs have been increasing, hurricanes have become larger and more frequent, sea level has risen, atmospheric temperatures have risen, the delta has been subsiding and, since 1930, has lost 1.2 million acres of land. This loss has had tremendous economic implications, including exposing cities like New Orleans to greater threats from hurricanes.

Hurricanes Katrina and Rita triggered a warning that has been sounded several times before. The current management of the Mississippi River, moving the sediment and fresh water of the river off the continental shelf has damaging economic costs in terms of land loss. The river has been walled off from the Mississippi River Delta since the 1930s. The public, academics and the State of Louisiana have sought to reconnect the river to the delta and utilize its sediment, water and energy to renew the processes that added land to the delta for thousands of years.

It is clear that restoration of the deltaic processes and levees are needed to secure public safety, economic assets and valuable ecosystem services.

A “do-nothing” scenario will result in continued land loss costing the U.S. at least $41 billion. A “hold the line” scenario could avoid the $41 billion, but would provide no additional benefits at a 3.5% discount rate. A third “sustainable restoration” option would avoid $41 billion in losses and secure an additional $21 billion in benefits, providing $62 billion in net present value benefits.

This analysis does not include many ecosystem services with clear economic value. It is part of a series of efforts to understand the value of the natural capital in the Mississippi Delta. More work is critically needed to understand how and what investments in diversions, levees or other structures can produce the best and most long-lasting benefits.

A major investment to restore the deltaic processes of the Mississippi River Delta is required to maintain or expand the vast value of this natural asset. The movement of water and sediment and the maintenance and expansion of land underlies the production of many economic benefits, including protection against hurricanes. Without this investment, people and economic assets will be forced to retreat from the coastline.

Ecological engineering must form the basis of delta restoration. High and rising energy costs will erode the economics of energy intensive options, such as levees and sediment pumping while water and sediment diversions utilize the Mississippi River's energy and can be easily maintained over many decades.

The overarching solution is well understood: large diversions of water and sediment from the Mississippi River are required to rebuild the Mississippi Delta and to secure the many benefits, including the economic productivity that the river provides. Management of more coarse sediments in the Mississippi Basin, currently trapped behind dams, should also be considered as these sediments will eventually be released in the next 100 years and can contribute substantially to the delta's restoration.

Overall, this study shows that a major investment of $15-20 billion for restoring the Mississippi River Delta to significantly increase land building would return at least four to five times that amount in the order of $62 billion in net present value at a 3.5% discount rate.

Once restored in a manner that allows the maintenance of natural processes, these wetlands will continue to support the economic health of the Mississippi River Delta. With the river reconnected to the delta, the system will be closer to self-maintaining at the operating cost for diversion structures.

Without a large investment in restoration, hurricane damage will clearly increase and other ecosystem services will be lost. The economic viability and habitability of the Mississippi River Delta will be threatened. This could result in vast losses to the country in terms of irreplaceable cultural and natural resources.

Within the context of the current financial crisis, investment in the restoration of the Mississippi River Delta provides high short and long term returns. The Army Corps of Engineers, Federal, State and local governments should dramatically increase expenditures for the restoration of the Mississippi Delta.

The Mississippi River Delta, the largest delta in North America, houses oil and natural gas resources, refineries, fertilizer and chemical facilities and other industries that are vital to the country's economic health. It also comprises 40% of U.S. coastal wetlands, a crucial flyway for migratory birds. It is by far the most productive delta in the United States.

Economies need nature. This is very evident in the Mississippi River Delta. If the Mississippi River is not reconnected to the delta on a large-scale basis, the land, culture and economy of this vast and productive area will be lost. Effective hurricane defenses require wetland expansion. Reconnecting the river to the delta at the appropriate scale will accomplish restoration that is needed. This is in the best interest of the people of the United States.

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APPENDICES

APPENDIX A: List of Value-Transfer Studies Used for Data Sources

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APPENDIX B: Table of Land Cover Type, Ecosystem Services, Valuation Study Authors, Low and High Values

Land Cover/Ecosystem Service	Valuation Study Author	Method	Minimum Value	Maximum Value
Fresh Marsh				
Carbon sequestration	Chmura et al., 2003; Pearce, 2001; Tol, 2005	MP	$29.43	$267.53
Gas regulation	Costanza et al., 1997		136.64	136.64
Nutrient regulation	Kazmierczak, 2001	RC	$3.13	$1,069.56
Water supply	AWWA. 2007	RC	$42.52	$113.39
Flood protection	Thibodeau et al, 1981	AC	5,957.20	5,957.20
Hurricane protection	Costanza , 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber, 1996	PF	$53.37	$74.46
Fur & alligator production	Lindstedt, 2005	MP	$4.33	$4.90
Recreation	Bergstrom et al., 1990	TC, CV	$134.44	$134.44
Aesthetic				
Fresh Marsh Total			**$1,661**	**$3,059**
Intermediate Marsh				
Carbon sequestration	Chmura et al. 2003; Pearce 2001, Tol 2005	MP	$29.43	$118.59
Nutrient regulation	Kazmierczak, 2001	RC	$3.13	$1,069.56
Water supply	AWWA, 2007	RC	$42.52	$113.39
Hurricane protection	Costanza et al., 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber, 1996	PF	$53.37	$74.46
Fur and alligator production	Lindstedt, 2005	MP	$4.26	$4.34
Recreation	Bergstrom et al., 1990	TC, CV	$134.44	$134.44
Aesthetic				
Intermediate Marsh Total			**$1,656**	**$2,910**
Brackish Marsh				
Carbon sequestration	Chmura et al. 2003; Pearce 2001, Tol 2005	MP	$29.43	$118.59
Nutrient regulation	Kazmierczak 2001	RC	$3.13	$1,069.56
Water supply	AWWA 2007	RC	$42.52	$113.39
Hurricane protection	Costanza et al., 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber 1996	PF	$53.37	$74.46
Fur & alligator production	Lindstedt 2005	MP	$4.26	$4.34
Recreation	Bergstrom et al. 1990	TC, CV	$134.44	$134.44
Aesthetic				
Brackish Marsh Total			**$1,658**	**$2,910**
Saline Marsh				
Carbon sequestration	Chmura et al. 2003; Pearce 2001, Tol 2005	MP	$29.43	$118.59
Nutrient regulation	Kazmierczak 2001	RC	$3.13	$1,069.56
Water supply	AWWA 2007	RC	$42.52	$113.39
Hurricane protection	Costanza et al., 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber 1996	PF	$53.37	$74.46
Recreation	Bergstrom et al. 1990	TC, CV	$134.44	$134.44
Aesthetic				
Saline Marsh Total			**$1,653**	**$2,905**

Wetland Forest				
Carbon sequestration	CCX n.d., Pearce 2001, Tol 2005	MP	$21.11	$191.87
Nutrient regulation	Kazmierczak 2001	RC	$3.13	$1,069.56
Water supply	AWWA 2007	RC	$42.52	$113.39
Flood protection	Th bodeau et al, 1981	AC	5,957.20	5,957.20
Hurricane protection	Costanza et al. 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber 1996	PF	$53.37	$74.46
Wetland Forest Total			**$1,515**	**$2,844**
Beach				
Disturbance protection	Parsons et al. 2001, Pompe and Rinehart 1995	HP	$20,814	$33,738
Recreation & aesthetic	Edwards and Gable 1991, Kline and Swallow 1998	HP, CV	$131	$42,654
Cultural	Taylor and Smith 2000	HP	$24	$24
Beach total			**$20,969**	**$76,416**
Cropland				
Recreation & aesthetic	Alvarez-Farizo et al. 1999, Bergstrom et al. 1985	CV	$25.77	$25.77
Pollination	Southwick and Southwick 1992, Robinson et al. 1989	MP, AC	$2.25	$11.34
Cropland total			**$28**	**$37**
Forest				
Carbon sequestration	Reyes and Mates 2004, Pimentel 1998	AC	$10.57	$13.33
Recreation & aesthetic	Willis 1991, Bishop 1992	TC, CV	$0.15	$543.42
Habitat refugia	Haener and Adamowicz 2000, Amigues et al. 2002	CV	$1.05	$2,158.01
Forest Total			**$12**	**$2,715**
Open Water				
Water supply	Piper 1997, Ribaudo and Epp 1984	CV, TC	$27.55	$718.62
Recreation & aesthetic	Patrick et al. 1991, Ward et al. 1996	TC	$1.44	$1,634.67
Open Water Total			**$29**	**$2,353**
Riparian Buffer				
Water supply	Rich and Moffitt 1982, Matthews et al. 2002	HP, CV	$4.40	$11,088.93
Disturbance prevention	Rein 1999	TC	$6.44	$200.84
Recreation & aesthetic	Greenley et al. 1981, Bowker et al. 1996	CV, TC	$7.30	$9,051.84
Cultural	Greenley et al. 1981	CV	$3.98	$3.98
Riparian Buffer Total			**$22**	**$20,346**
Urban Open Space				
Climate regulation	McPherson et al. 1998, McPherson 1992	MP, AC	$25.12	$819.68
Recreation & aesthetic	Tyrvainen 2001	CV	$1,181.85	$3,464.50
Water regulation	McPherson 1992	AC	$5.63	$5.63
Urban Open Space Total			**$1,213**	**$4,290**

Wetland				
Water supply	Lant and Tobin 1989, Pate and Loomis 1997	CV	$169.64	$3,065.76
Recreation & aesthetic	Th bodeau and Ostro 1981, Doss and Taff 1996	CV, TC	$26.81	$3,942
Habitat refugia	Vankooten and Schmitz 1992	CV	$5.04	$5.04
Water regulation	Th bodeau and Ostro 1981	AC	$5,957.20	$5,957.20
Wetland Total			**$6,159**	**$12,970**
Estuary				
Water supply	Whitehead et al. 1997, Bockstael et al. 1989	CV	$5.53	$119.79
Recreation & aesthetic	Whitehead et al. 1997, Johnston et al. 2002	CV, TC	$1.27	$332.79
Habitat refugia	Farber and Costanza 1987, Johnston et al. 2002	PF	$10.82	$1,298.23
Estuary Total			**$18**	**$1,751**
Saltwater Wetland				
Nutrient regulation	Breaux et al. 1995	AC	$102.86	$16,560.46
Habitat refugia	Lynne et al. 1981, Bell 1997	PF, FI	$1.10	$953.01
Saltwater Wetland Total			**$104**	**$17,513**

APPENDIX C: Limitations of Approach

Transferred value analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem. Like any economic analysis, this methodology has strengths and weaknesses. Because this is a meta-study, it has greater opportunity or error, and as the numbers show, a very wide range between low and high estimates. Some have objected to this approach on the grounds that:

1. Every ecosystem is unique; per acre values derived from another part of the world may be irrelevant to the ecosystems being studied.
2. Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values). This remains to be an important issue even though this was partly addressed in the spatial modelling component of this project.
3. Gathering all the information needed to estimate the specific value for every ecosystem within the study area not feasible. Then the “true” value of all of the wetlands, forests, pastureland, etc. in a large geographic area; cannot be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.
4. To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of “exchange” value; we cannot conceive of a transaction in which all or most of a large area’s ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income accounts aggregates and not exchange values (Howarth & Farber, 2002). These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative that amounts to limiting valuation to a single ecosystem in a single location and only using data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. For an area with the size and landscape complexity of the Mississippi River Delta, this approach will make valuation extremely difficult and costly at this point in time.

In effect, these proponents would look at the problem of conducting a house appraisal as an impossible goal. The comps, other houses sold in the neighborhood, never match well enough to make an estimate. However, they would advocate an estimate the dollar value of a bathroom, stove or door knob with good precision.

Responses to these critiques can summarized as follows (See Costanza et al 1998 and Howarth and Farber 2002 for more detailed discussion):

1. While every wetland, forest, or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more and no less justified than their use in other “macroeconomic” contexts, e.g., developing economic

statistics such as Gross Domestic or Gross State Product. This study's estimate of the aggregate value of the Mississippi River Delta's ecosystem services is a valid and useful (albeit imperfect, as are all aggregate economic measures) basis for assessing and comparing these services with conventional economic goods and services.

2. The results of the spatial modelling analysis that were described in other studies do not support an across-the-board claim that the per-acre value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and probably other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, a major indicator of ecosystem health – and by implication of services tied to NPP – where each acre makes about the same contribution to the whole regardless of whether it is part of a large patch or a small one. This area of inquiry needs further research, but for the most part the assumption (that average value is a reasonable proxy for marginal value) seems appropriate as a first approximation.

3. As employed here, the prior studies we analyzed (most of which were peer-reviewed) encompass a wide variety of time periods, geographic areas, investigators, and analytic methods. Many of them provide a range of estimated values rather than single point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Limited sensitivity analyses were performed. The approach is similar to defining an asking price for a piece of land based on the prices for "comparable" parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure, even to the extent of publicizing a single asking price rather than a price range.

4. The objection as to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of *all* of the world's ecosystems. Leaving that debate aside, one can in fact conceive of an exchange transaction in which all or a large portion of, e.g., Louisiana's wetlands were sold for development, so that the basic technical requirement that economic value reflect exchange value could in principle be satisfied. But even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose more analogous to national income accounting than to estimating exchange values (cf. Howarth and Farber 2002).

In the last analysis, this report takes the position that "the proof is in the pudding", i.e., the possibility of plausibly estimating the value of an entire state's ecosystem services is best demonstrated by presenting the results of an attempt to do so. In this report we have tried to display our results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services it seems better to be approximately right than precisely wrong.

The estimated value of the world's ecosystems presented in Costanza et al. (1997) has been criticized as both (1) "a serious underestimate of infinity" and (2) impossibly exceeding the entire Gross World Product. These objections seem difficult to reconcile, but that may not be so. Just as a human life is "priceless" so are ecosystems, yet, people get paid for work. Thus Costanza's estimate of the work that ecosystem do, is an underestimate of the "infinity" of pricelessness because that is not what he estimated. That the value ecosystems provide to people exceeds the gross world product should, perhaps not be so surprising. Consider the value of one ecosystem service, photosynthesis, and the ecosystem good it produces, atmospheric oxygen, neither valued in Costanza's study. Given the choice between breathable air, and possessions, informal surveys have shown the choice of oxygen over stuff is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product. That is only a single ecosystem service and good.

In terms of more specific concerns, the value transfer methodology introduces an unknown level of error, because we usually do not know how well the original study site approximates conditions in the Mississippi River Delta, with the exception of some wetlands studies that were conducted in this area. Other potential sources of error in this type of analysis have been identified (Costanza et al. 1997) as follows:

1. Incomplete coverage is perhaps the most serious issue. Not all ecosystems have been well studied and some have not been studied at all as is evident from the gap analysis presented below. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of less than zero.
2. Distortions in current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of "true" values.
3. Most estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously been aware of.
4. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. If the Mississippi River Delta's ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in "supply" appear likely as land conversion and development proceed; climate change may also adversely affect the Mississippi River Delta's ecosystems (e.g., more intense hurricanes), although the precise impacts are harder to predict.
5. The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services (Limburg et al. 2002).
6. As noted above, the method used here assumes spatial homogeneity of services within ecosystems. The spatial modeling component of the project was intended to address this issue and showed that, indeed, the physical quantities of some services vary significantly with spatial patterns of land use and land cover. Whether this fact would increase or decrease valuations is unclear, and depends on the specific spatial patterns and services involved.
7. Our analysis uses a static, partial equilibrium framework that ignores interdependencies and dynamics. More elaborate systems dynamics studies of ecosystem services have shown that including

interdependencies and dynamics leads to significantly higher values (Boumans et al. 2002), as changes in ecosystem service levels ripple throughout the economy.

8. The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.
9. The approach does not fully include the “infrastructure” or “existence” value of ecosystems. It is well known that people value the “existence” of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.
10. There are great difficulties and imprecision in making inter-country comparisons on a global level. This problem was of limited relevance to the current project, since the majority of value transfer estimates were from the U.S. or other developed countries.
11. In the few cases where we needed to convert from stock values to annual flow values, the amortization procedure also creates significant uncertainty, both as to the method chosen and the specific amortization rate used. (In this context, amortization is the converse of discounting.)
12. All of these valuation methods use static snapshots of ecosystems with no dynamic interactions. The effect of this omission on valuations is difficult to assess.
13. Because the transferred value method is based on average rather than marginal cost, it cannot provide estimates consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

The result would most likely be significantly higher values if these problems and limitations were addressed. Unfortunately, it is impossible to know how much higher the values would be if these limitations were addressed. One example may be worth mentioning, however. Boumans et al. (2002) produced a dynamic global simulation model that estimated the value of global ecosystem services in a general equilibrium framework to be roughly twice of what Costanza et al estimated using a static, partial equilibrium analysis. Whether a similar result would obtain for the Mississippi River Delta is impossible to say, but it does give an indication of the potential range of values.

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US Army Corps
Of Engineers
St. Paul District

UPPER ST. ANTHONY FALLS LOCK AND DAM, LOWER ST. ANTHONY FALLS LOCK AND DAM, AND LOCK AND DAM NO. 1

MINNEAPOLIS, MINNESOTA

SECTION 216 DISPOSITION STUDY
Decision Meeting Briefing Report

16 August 2017

Prepared by U.S. Army Corps of Engineers
St. Paul District

EXECUTIVE SUMMARY

This draft report gives an overview of the Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1 projects, and provides information with which to make a decision whether or not to proceed with a full disposition study for one or more of these Federally-owned sites. A disposition study would result in a recommendation to deauthorize and dispose of one or more of these Federally-owned lock facilities and lands.

Section 2010 of the Water Resources Reform and Development Act of 2014 (WRRDA 2014), dated 10 June 2014, directed the Upper St. Anthony Falls (USAF) lock and dam, located at Upper Mississippi River mile 853.9 in Minneapolis, Minnesota, be closed within one year of the date of enactment of the Act. Section 2010 of WRRDA 2014 allows for emergency lock operations at USAF as necessary to mitigate for flood damage.

Section 2010 of WRRDA 2014 directed the closure, but not the deauthorization, of USAF lock. A concern related to the lock closure was the threat of the upstream movement of Asian Carp making their way up the Mississippi River system, but this was not addressed in the WRRDA language and was not formally identified as a reason for closing the lock. It is uncertain what role the lock plays in deterring the range expansion of Asian carp and other aquatic invasive species.

WRRDA 2014 terminated navigational operations at the USAF site. Prior to the closure of the lock at Upper St. Anthony Falls, the three locks located in the Minneapolis-St. Paul metropolitan area of Minnesota, (USAF, LSAF and L/D 1), operated as a system to support navigation on the upper reaches of the Mississippi River nine-foot navigation channel. With the lock at Upper St. Anthony Falls closed to navigation, the demand for both commercial and recreational lockage at LSAF and L/D 1 has decreased due to the navigational disconnect in the Mississippi river at USAF. Disposition of one or more of the three sites may be warranted if the sites are deemed to not be fulfilling their authorized purposes and are therefore no longer serving a Federal interest. The current authorized purposes are navigation and recreation.

An Initial Appraisal (IA) was conducted in 2015 to determine if conditions exist which may warrant further analysis on a completed project as authorized by Section 216 of the Flood Control Act of 1970 (PL 91-611). The IA recommended investigation under the authority of Section 216 of PL 91-611 the future use or disposition of USAF Lock and Dam, of Lower St. Anthony Falls (LSAF), and of Lock and Dam and Lock and Dam No. 1 (L/D 1).

As per the August 2016 disposition study interim guidance for conducting disposition studies, the objective of the 16 August 2017 Agency Decision Meeting will be to determine if the appropriate action is “No Action” or “Proceed with a Disposition Study”. This Decision rests with the Chief of Policy and Planning, and will be the outcome of the August 16, 2017 Decision Meeting.

DISPOSITION REPORT
Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1

Section 216 Disposition Study
Decision Meeting Briefing Report
16 August 2017

PURPOSE OF THIS REPORT

The purpose of this Agency Decision Meeting Briefing Report is to present information with which to determine whether or not the Upper St. Anthony Falls Lock and Dam, the Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1 (USAF, LSAF and L/D 1) projects continue to serve a Federal interest. If not, the appropriate action may be to conduct a full disposition study, culminating in deauthorization of one or more of the projects and disposal of all Federal interests.

This disposition study briefing report considers two alternatives regarding the deauthorization of Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1 (USAF, LSAF and L/D 1). These two alternatives are "No Action" and "Proceed with a full disposition study". This briefing report is intended to aid the discussion by the Corps Vertical Team, in determining the appropriate course of action.

If indicated, a disposition study will follow the six-step planning process defined in the Planning Guidance Notebook ER-1105-2-100. The study is performed in three iterations of the planning process in support of the three study milestones, the Decision Meeting, the Tentatively Selected Plan, and the Final Report Milestones. This briefing report is the first iteration and supports the Decision Meeting Milestone.

STUDY TIMELINE

Table 1 – Proposed Study Timeline

Received Supplemental Draft Guidance from HQ's USACE	22 August 2016
Received Funding for Disposition Study	18 May 2017
Decision Meeting	16 August 2017
Tentatively Selected Plan Milestone	September 2018
Final Report	August 2019

EXISTING STUDY GUIDELINES

a) Execution of Disposition Studies - Fiscal Year 2016, PB 2016. Issued February 2016

b) Interim Guidance of the Conduct of Disposition Studies Issued August 22, 2016

c) ER 1105-2-100, Planning Guidance Notebook.

d) ER 1110-2-1156, Safety of Dams - Policies and Procedures

e) Public Law 91-611, Section 216, December 1970

PROJECT HISTORY AND AUTHORIZATION

History

The Upper Mississippi River (UMR) is an ecologically and economically important and historic waterway. Navigation of the river was unreliable between St. Paul, Minnesota and St. Louis, Missouri due to variable river depths, sandbars, rocks and snags. Since the early 19th century, river channel improvements resulted from private, State, and Federal efforts, which primarily consisted of dam construction, dredging, and snagging. The River and Harbor Act of 1866 allowed for the funding of permanent improvements to the UMR for commercial traffic administered by the United States Army Corps of Engineers (Corps).

By the late 19^{th} century the construction of wing dams and other river training structures created a four-and-one-half foot navigation channel to St. Paul. Minneapolis civic leaders long desired to make the city the head of navigation on the Mississippi River. The river gorge above St. Paul was filled with debris from the recession of St. Anthony Falls with a hundred foot drop from the cascade to St. Paul. In 1907 the Meeker Island Dam was completed within the gorge. The same year Congress authorized a six-foot channel. Construction of Government Lock and Dam 1 (LD 1) was completed in 1917 (subsequently, the upstream Meeker Island Dam was partially demolished and submerged).

In 1927 Minneapolis constructed a barge terminal below St. Anthony Falls although it was not convenient for railroad or vehicular access. Meanwhile, with continued marine technology advances and increased barge capacity, the Nine-Foot Channel was authorized by River and Harbor Act in 1930. The Nine-Foot Channel created a system of of 26 locks and dams that would create a series of slackwater pools from the base of St. Anthony Falls to St. Louis. This included the existing structures at LD 1 and Lock and Dam 2 at Hastings, Minnesota. Still unsatisfied with its barge terminal location and with more suitable sites situated above the falls, boosters advocated for an extension of the navigation channel above the falls.

In 1937 the Upper Minneapolis Harbor Development Project was authorized. Two complexes were required to ascend the 74 foot drop of the cataract: Lower St. Anthony Falls Lock and Dam (LSAF), completed in 1956; and the Upper St. Anthony Falls Lock and Dam (USAF), completed in 1963.

Authorizations

The Rivers and Harbors Act of July 1930 (PL 71-520) established the Upper Mississippi River nine-foot navigation channel project. The project purpose was expanded to include recreation under the Flood Control Act of 1944 (PL 78-534). The Rivers and Harbors Act of 1937 (PL 75-392) authorized the Upper and Lower St. Anthony Falls Locks and Dams and the Minneapolis Upper Harbor Project, which extended the nine-foot channel upstream to river mile 857.6.

Congress originally authorized the construction of Lock and Dam Number 1 on March 3, 1899. The project was re-authorized by the River and Harbor Act of 25 June 1910. The River and Harbor Act of 1927(PL 69-560) authorized a survey of the Mississippi River between the Missouri River and Minneapolis, Minnesota. The River and Harbor Act of 1930 included Lock 1 in its authorized nine-foot channel project.

While flood risk management is not an authorized purpose, Section 2010 of the WRRDA 2014, which directed closure of USAF, directed that nothing in the Act would prevent USAF from being operated for flood damage mitigation.

PRIOR STUDIES AND REPORTS

Several studies and reports have been completed for the study area. The following is a discussion of recent studies and projects of significance in the study effort. Additional studies and reports are listed in the references section at the end of this document.

<u>Initial Appraisal – Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1, Minneapolis, Minnesota, Section 216.</u> U.S. Army Corps of Engineers, St. Paul District, dated 5 October 2015, with 6 November 2015 revisions. Supporting documentation for requesting a Section 216 Study.

<u>Environmental Assessment, Closure of Upper St. Anthony Falls Lock to Commercial and Recreational Navigation Traffic, Hennepin County, MN.</u> U. S. Army Corps of Engineers, dated February 2015, with Findings of No Significant Impact, dated 25 February 2015.

<u>Assessment of Economic Impact of Potentially Discontinuing the Operation of the Upper St. Anthony Falls Lock</u>. Metropolitan Council, Publication 14-12-020, dated 9 July 2012. Closure of the lock would impact barge traffic to the Upper Riverfront of Minneapolis. The study analyzes the changes to transportation and business that would result and the effect of those changes on the economy and users of the locks.

<u>Final Environmental Assessment, Closure of the Upper St. Anthony Falls Lock to Commercial and Recreational Navigation Traffic, Hennepin County, MN</u>. U.S. Army Corps of Engineers, St. Paul District, dated February 2015. An Environmental Assessment was prepared by the St. Paul District in regards to the effects of closing the lock.

<u>St. Anthony Falls Regional Park Master Plan</u>, Minneapolis Park and Recreation Board, draft December 2014. This plan describes recommendations for land-use policy, park development, phasing, implementation strategies and environmental stewardship.

SECTION 216 STUDY AUTHORITY

Section 216 of the Flood Control Act of 1970 (PL 91-611) authorizes investigations for the modification of completed projects or their operation when found advisable due to significantly changed physical or economic conditions and for improving the quality of the environment in the overall public interest. Section 216 states:

"The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and for improving the quality of the environment in the overall public interest."

PROJECT LOCATIONS

The three projects are located on the Mississippi River in Minneapolis, Minnesota. Upper St. Anthony Falls Lock and Dam is located on the right bank of the Mississippi River in Minneapolis, Minnesota, at Upper Mississippi River mile 853.9. Lower St. Anthony Falls Lock and Dam is located on the right bank of the Mississippi River in Minneapolis, Minnesota, at Upper Mississippi River mile 853.3. Lock and Dam 1 is located on the right bank of the Mississippi River in Minneapolis, Minnesota at Upper Mississippi River mile 847.9.

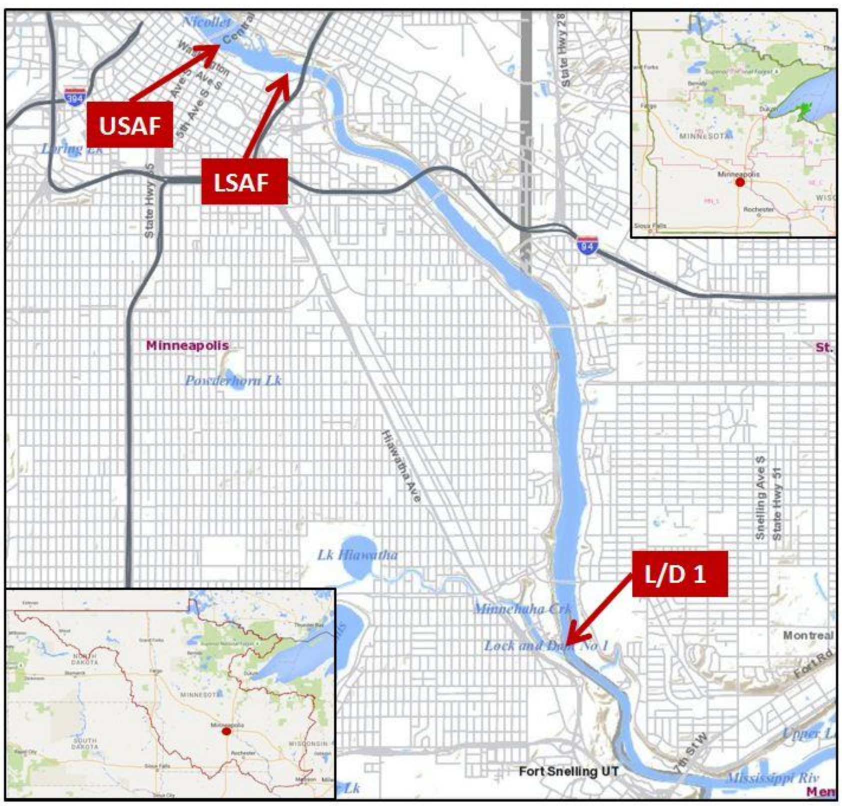

Figure 1 - Twin Cities locks and dams - General Location

These three sites make up the top three steps in the upper Mississippi River "stairway of water" which, until the USAF lock was closed in June 2015, provided for commercial navigation to Minneapolis, Minnesota, as shown in Figure 1. The locations of these three projects are shown in Figures 3 through 5. These three sites are referred to elsewhere in this document as the Twin Cities locks and dams.

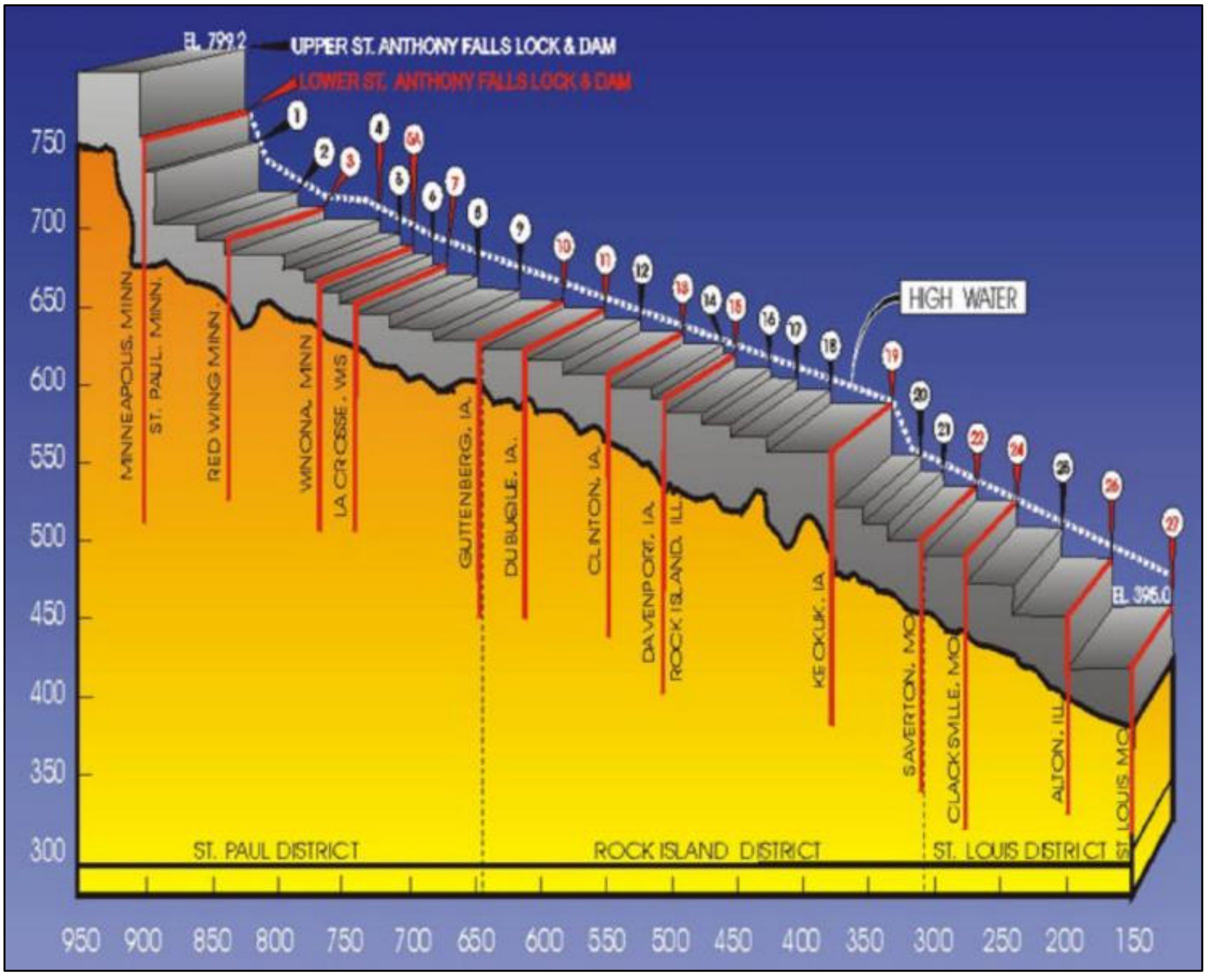

Figure 2 - Upper Mississippi River Stairway of Water

Figure 3- Upper St. Anthony Falls lock and dam

Figure 41 Lower St. Anthony Falls lock and dam

Figure 5 Lock and Dam 1

DAM SAFETY ACTION CLASSIFICATION SYSTEM/EXISTING SAFETY EVALUATION

The Dam Safety Action Classification (DSAC) is intended to provide consistent and systematic guidelines for appropriate actions to address the safety issues and deficiencies of USACE dams. USACE dams are placed into a DSAC class based on their individual dam safety risk considering both the likelihood of failure and the consequences associated with a failure. The consequence category includes life safety, economic, and environmental risk resulting from a dam failure. DSAC classes have 5 levels as indicated below:

- DSAC 1 (Very High Urgency of Action)
- DSAC 2 (High Urgency)
- DSAC 3 (Moderate Urgency)
- DSAC 4 (Low Urgency)
- DSAC 5 (Normal)

Upper and Lower St. Anthony Falls and Lock 1 were all assigned DSAC ratings based on a screening level Portfolio Risk Analysis (SPRA). This analysis screened every dam in the USACE inventory based on readily available information. The screening used a risk based algorithm and assigned unfavorable assumptions when information was not readily available. More recently, all three dams were more intensively evaluated using a semi-quantitative risk assessment process as part of the USACE periodic assessments during 2015 – 2016; and the DSAC ratings were updated in 2017.

USAF was initially categorized as a DSAC 3 based on SPRA in 2009. The primary reasons for the USAF DSAC category were: (1) scour erosion of the St. Peter sandstone about the main spillway of Horseshoe Dam, (2) seepage and piping failure of a 1800's mill tunnel in rock within the right abutment, and (3) failure of a wooden sluice gate in the masonry wall of the Concrete Abutment Tie-In Dam. The Periodic assessment (PA) for St. Anthony Falls Locks and Dams was presented to the Dam Senior Oversight Group (DSOG) on 12 April 2017. The incremental risks are primarily driven by potential breach of the upper dam that would impact the Minneapolis water supply. The highest risk PFM was overtopping of an earthen dam lined with a masonry wall. The highest source of economic consequences involves impacts to the City of

Minneapolis water intake for municipal water supply. This was estimated at $65 million per month for an affected population of 573,000 people. Economic consequences for navigation were $1.8 million per month prior to lock closure. Hydropower is about $0.6 million per month. The highest source of economic consequences for a dam failure involves impacts to the City of Minneapolis water intake for municipal water supply, affecting 573,000 people, at a cost of $65 million per month. Impacts for loss of hydropower at Upper St. Anthony Falls are $0.6 million per month. Based on a detailed review of all project data, the project was re-classified from DSAC 3 to DSAC 4. The change is mostly driven by the negligible life safety risks as well as the very low economic risks.

LSAF was initially categorized as a DSAC 4 based on SPRA in 2008. The primary reasons for the LSAF category included: (1) over-topping, (2) slope instability and (3) seepage and piping along the rock interface of the earth embankment cofferdam built by Xcel Energy. The LSAF concerns were all resolved when Xcel Energy backfilled the non-overflow earth embankment dam and raised the crest in 1996, although there is some concern for overtopping. The incremental risks are primarily driven by potential breach of the upper dam that would impact the Minneapolis water supply. The highest risk PFM was overtopping of the earthen dam. The economic consequences for LSAF are small relative to USAF since the lower dam will not impact the City of Minneapolis water intake, although the project is part of the system that maintains the falls. Economic consequences for navigation were $1.8 million per month prior to lock closure. Hydropower is less than $1.0 million per month. Based on a detailed review of all project data, the project was re-classified from DSAC 4 to DSAC 5. The change is mostly driven by the low economic risks and the negligible life loss consequences.

L&D 1 was initially categorized as DSAC 2 based on SPRA in FY 08. The primary reasons were internal erosion related failure modes for the foundation of both the Ambursen Dam and powerhouse structure. The risk of internal erosion was influenced by the 1987 failure of a powerhouse at Lower St. Anthony Falls with similar foundation conditions. A semi-quantitative risk assessment (SQRA) for Locks and Dam No. 1 was presented to the Dam Senior Oversight Group (DSOG) on 3 February 2017. The current assessment of incremental risks are primarily driven by internal erosion related failure modes for the foundation of both the dam and powerhouse structure. Each of the internal erosion failure modes exhibit a relatively high global gradient (0.2-0.3 range), have unfiltered exits, and are submerged such that detection and intervention is considered highly unlikely. Although the dam has fairly significant head difference (37.9 feet) at normal operating pool, the life safety consequences are not measureable and the economic consequences are low or moderate. There is no anticipated loss of life for any of the failure modes evaluated by the SQRA team. Based on a detailed review of all project data, the project was reclassified from DSAC 2 to a DSAC 4. The change was mostly driven by the low likelihood of life loss. Impacts for loss of hydropower operation at the site are $10.3 million per year.

HISTORIC AND EXISTING CONDITIONS

Upper St. Anthony Falls Lock and Dam

Upper St. Anthony Falls Lock and Dam was authorized by the Rivers and Harbors Act of 1930 (PL 71-520) and the Rivers and Harbors Act of 1937 (PL 75-392). Construction began in 1959 and was completed in 1963. Upper St. Anthony Falls was placed in operation in September of 1963.

The main features of Upper St. Anthony Falls include a 56-foot-wide by 400-foot-long main lock with a hydraulic lift of 49.2 feet . The lock is connected to a 2,045 foot-long horseshoe dam owned by Xcel Energy Corporation, and a 425-foot long straight-chord main spillway below the horseshoe dam, also owned by Xcel energy. The horseshoe dam is surmounted by a wooden flashboard system, which raise the crest of the dam from 796.8 feet to 798.8 feet above mean sea level (1912 adjusted datum). There are short segments of gravity walls connecting the lock to adjacent structures and embankments.

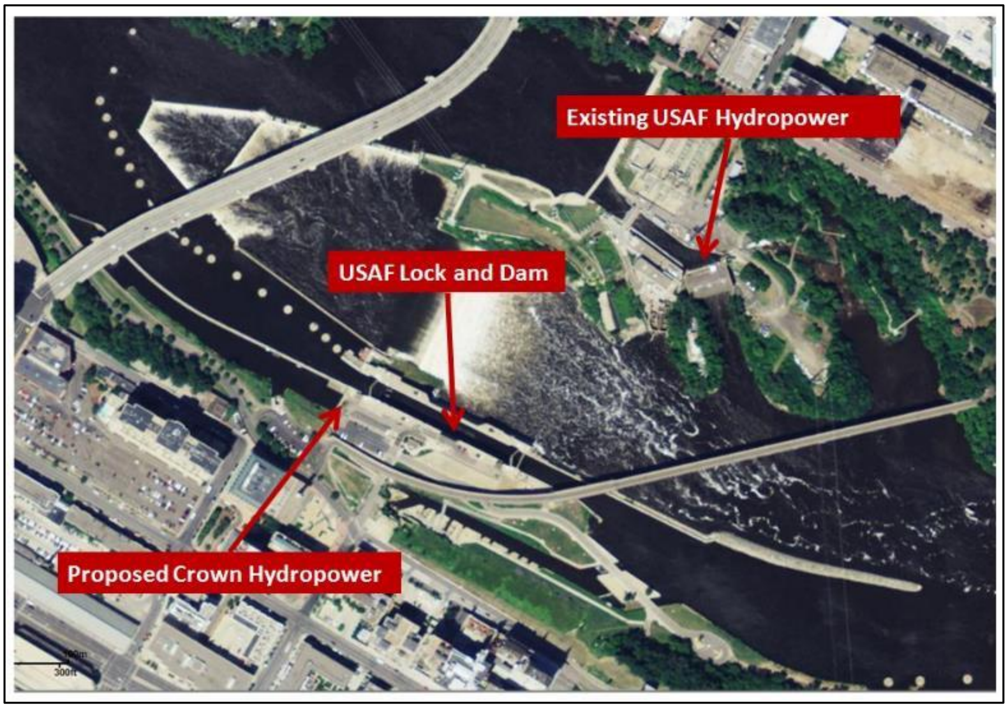

Figure 6 Upper St. Anthony Falls lock and dam

Figure 7 USAF Lock Chamber

Additional features include upper and lower miter gates; a submersible Tainter gate used for flood risk management; upper and lower control stations; gate operating equipment; a central control station with an observation deck (Figure 11), an elevator and attached shop maintenance facilities; public restrooms; one upper small boat davit with lifeboat for emergency use; security fencing and facilities; lighting; a parking area located at the terminus of Portland Avenue; and an access road leading to the lower lock.

Figure 2 Horseshoe Dam and Spillway at USAF

Figure 39 USAF Control Station and Observation Deck

In the time since the upper lock was closed to navigation on June 9, 2015, the upper lock continues to be used for flood risk management, public tours, and as a launching point for emergency water rescues. The observation deck/visitor center and other points on the site have interpretive displays. The Corps has granted the National Park Service a 5-year real estate license to conduct public tours during the summer. The lock is important as part of the damming surface which maintains the pool elevation upstream of St. Anthony Falls. The intakes for the Minneapolis city water supply are located upstream of the falls, and are sensitive to drops in upstream water level. The USAF Hydropower project is also sensitive to a drop in upstream water level.

Lower St. Anthony Falls Lock and Dam

Lower St. Anthony Falls Lock and Dam was authorized by the Rivers and Harbors Act of 1930 (PL 71-520) and the Rivers and Harbors Act of 1937 (PL 75-392). Construction began in 1950 and was completed in 1956. Lower St. Anthony Falls lock and dam was placed in operation in November 1956.

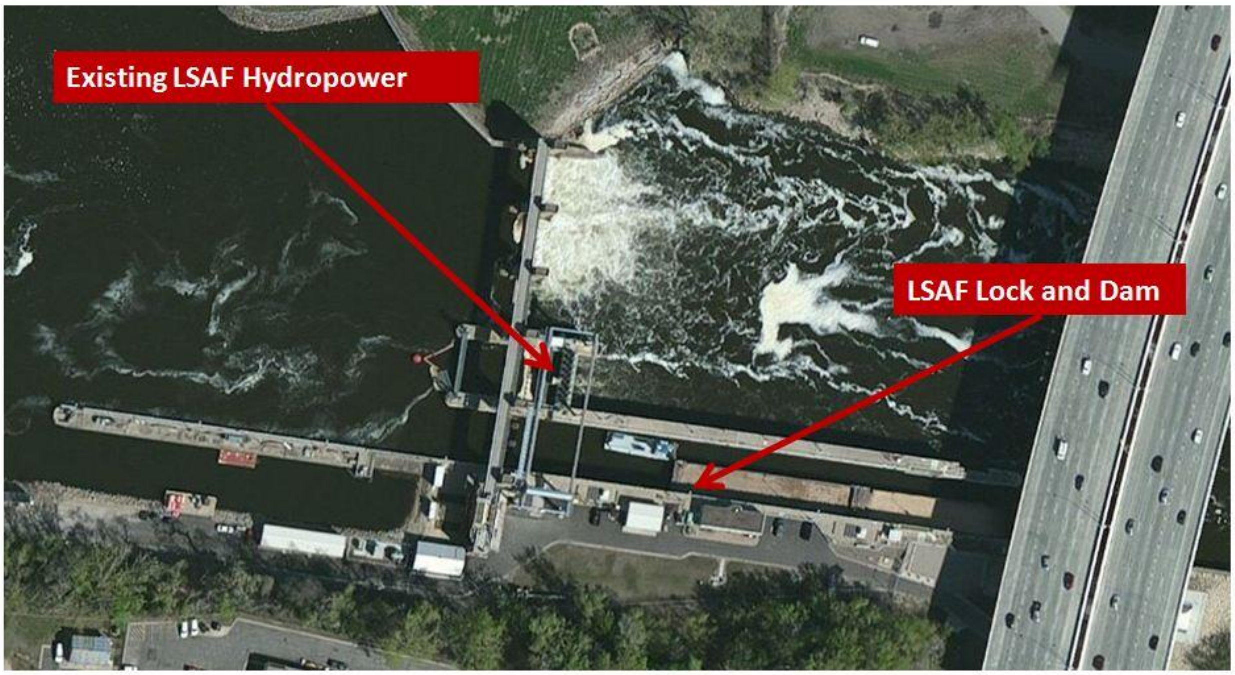

Figure 10 Lower St. Anthony Falls lock and dam

The main features of Lower St. Anthony Falls include a 56-foot-wide by 400-foot-long main lock with a hydraulic lift of 25 feet, and a 475-foot-long dam spanned by an overhead bridge supported on 7 piers, a 56-foot-wide unfinished auxiliary lock housing the LSAF hydropower facility, three 56-foot-wide moveable dam Tainter gates, and a concrete abutment wall. The Corps' abutment wall ties into an earthen embankment on the north side of the dam, which is owned by Xcel Energy.

Figure 4 LSAF Lock Chamber

Additional features include an upper lock Tainter gate (which is submerged to permit navigation); a lower miter gate; upper and lower control stations; gate operating equipment; a central control station; a separate shop maintenance facility; a warehouse building; one upper and one lower small boat davit with lifeboats for emergency use; a bulkhead storage area; security fencing and facilities; lighting; a parking area, and access roads leading to the upper lock and to West River Parkway.

Figure 12 LSAF Dam, LSAF Hydropower Project,Located in Auxiliary Lock (center)

Other on-site facilities that are owned and operated by Brookfield Renewable Power as part of the LSAF hydropower plant include: an electrical generating facility located in the auxiliary lock chamber, consisting of an operating gallery, 16 hydromatrix turbines and generating equipment; an overhead gantry crane spanning the main and auxiliary lock chambers; an electrical switchyard; an operations control building; and additional security and monitoring features.

The LSAF hydropower facility is currently owned and operated by Brookfield Renewable Energy under FERC license P-12451. As part of its FERC license, the hydropower plant provides free electricity to Lower St. Anthony Falls lock and dam. The operation of the LSAF Hydropower project is also governed by Use, Occupation and License Agreement No. DACW37-10-0125, signed between Brookfield Renewable Power and the Corps on November 15, 2010.

Figure 13 LSAF Hydropower under construction (looking downstream from service bridge)

In the time since the upper lock was closed to navigation on June 9, 2015, the lower lock continues to be used for flood risk management, hydropower operation and navigation. While the lower lock is open for navigation, the primary users are mainly commercial tour boats and recreational users. There are no commercial ports located in the pool between LSAF and USAF locks. The hours of operation for navigation are currently 10 hours per day, seven days per week. Both the main lock and the auxiliary lock Tainter gates can be used to pass high river flows, in addition to the three dam gates. During flood conditions, the LSAF hydropower operator can lift the 16 hydromatrix turbines out of the water, allowing the free flow of floodwaters through the auxiliary chamber. All lock and dam Tainter gates are operated by lifting from the overhead bridge.

Lock and Dam 1

Lock and Dam 1 was originally authorized by Congress in March 3, 1899. The project was further authorized by the River and Harbor Act of 1910, and the River and Harbor Act of 1930.

The original 80-foot by 360-foot lock at Lock and Dam 1 was completed and placed in operation in 1917 and included foundations for a future hydropower project. In 1929, the original lock failed, cutting off all barge traffic to Minneapolis. To insure against a future interruption in barge traffic, a decision was made to build twin locks, each 56-feet by 400-feet at this site. The first (riverward) lock was completed in 1930, and the second (landward) lock was completed in May 1932. The riverward lock is no longer used for navigation. Lock and Dam 1 underwent major rehabilitation between 1978 and 1983. The hydropower plant located at Lock and Dam 1 was constructed by the Ford Motor Company in 1924.

Figure 14 Lock and Dam 1

The main features of Lock and Dam 1 include a 56-foot-wide by 400-foot-long main lock, with a hydraulic lift of 37.9 feet, and an inactive 56-foot-wide by 400-foot-long riverward lock. A 574-foot-long Ambursen-type concrete overflow spillway lies between the lock and the hydroelectric project. The Ambursen dam is equipped with eight 6-foot by 6-foot sluiceways, with slide gates, which can be used to draw the pool down for maintenance. Only three of the eight gates are maintained in workable condition. The three gates had hydraulic operating machinery installed in 1954.

Figure 15-Lock and Dam 1

The Ambursen dam is surmounted by a bladder-type flashboard system, which is operated and maintained by the hydropower company. The flashboards atop the Ambursen dam increase its top elevation from 723.1 feet to 725.1 feet above mean sea level (MSL 1912 adjustment). All river flows either pass through the hydropower plant or over the Ambursen dam. The Corps has no flood risk management capability at the dam. The flow capacity through the hydropower plant is 6,667 cubic feet per second. The spillway and the hydropower plant are shown in Figure 16.

Figure 16 - L/D 1 Spillway and Hydropower Plant

The hydropower plant has four turbine-generator units, with a total capacity of 14.4 MW. As part of its FERC license, the hydropower plant provides free electricity to Lock and Dam 1. The hydropower license has been renewed by FERC twice, once in 1974 and once in 2004. As part of the most recent license renewal, on October 15, 2004, the Corps and the Ford Motor Company (the license holder at the time), signed Use, Occupation and License Agreement number DACW37-3-050083, governing the terms of occupation of the Federal project. Brookfield Renewable Energy purchased the hydropower license from the Ford Motor Company in 2011. The hydropower project was renamed Twin Cities Hydro at that time.

Additional features of Lock and Dam 1 include: an upper miter gate; a lower miter gate (Figure 16); upper and lower control stations; gate operating equipment; a central control station; a separate shop maintenance facility with stairways and an elevator for public access to an elevated walkway and public restrooms; one upper and one lower small boat davit with lifeboats for emergency use; a bulkhead storage area; interpretive displays; security fencing and facilities; lighting; a parking area, and an access road leading to West River Parkway.

Figure 17- L/D 1 Lower Miter Gate

In the time since the Upper St. Anthony Falls lock was closed to navigation on June 9, 2015, Lock and Dam 1 continues to be used for hydropower operation, self-guided public tours, and navigation. While the lock is open for navigation, the primary users are mainly commercial tour boats and recreational users. The pool between Lock and Dam 1 and LSAF lock has one dredged material placement site that currently provides beneficial use, but there are no other commercial ports located in the pool. The hours of operation for navigation are currently 10 hours per day, seven days per week.

REAL ESTATE INTEREST

Upper St. Anthony Falls Lock & Dam (USAF) and Lower St. Anthony Falls Lock & Dam (LSAF)

The purpose of Saint Anthony Falls locks (SAF) was to extend navigation to Minneapolis, Minnesota. Project construction of SAF consisted of removing a portion of a hydropower dam to construct the upper lock; building the upper and lower locks and associated support buildings; removing the lower hydropower dam and replacing it with the LSAF lock and dam; constructing an access road between the two locks; dredging below the lower lock, between the two locks, and from the upper lock 3 miles upstream to a turning basin within the river for the Minneapolis Upper Harbor.

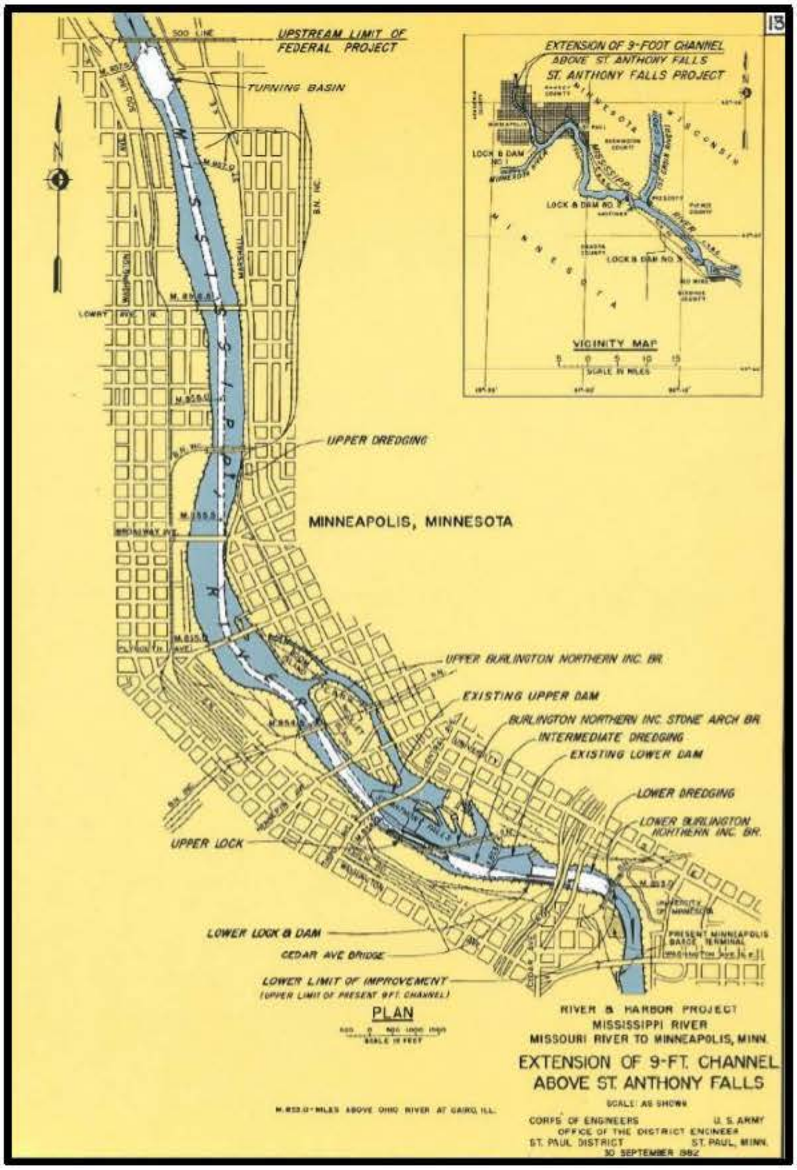

Figure 18 - 1982 Map showing extension of 9-foot channel and location of dredged material disposal sites - Upper and Lower St. Anthony Falls Locks and Dams

Upper St. Anthony Falls Lock & Dam (USAF)

A total of 9.01 acres of Lands, Easements, and Right-of-Way was acquired for the Upper Saint Anthony Falls (USAF) portion of the Mississippi River 9-ft Navigation Channel. The City of Minneapolis agreed to provide all necessary land interests for the project. All lands were acquired in Hennepin County, Minnesota. Fee lands consist of 6.83 acres and easement interests are 2.18 acres. Easement interests are a mix of flowage, road access, and utility easements. Some of the utility easements are placed under streets. Northern States Power Company (NSP) deeded fee lands and a small portion of their power facility's dam directly to the US. They were required to permit their lands and facility to be utilized as a compatible use to the Federal Navigation facility. This deed contains a reservation to NSP for their continued use for their facility. Any disposition will need to recite this retained right in the disposal deed. All fee lands at USAF were provided by NSP.

Figure 19 - Aerial View of USAF, Google Earth image date 4/5/2017

Inventoried Real Property includes the upper lock, visitor center/control building, a multi-use storage building, parking lots, paved road, and security fencing.

Figure 20 - USAF visitors' center & control building with lock chamber visible, image date – 2017.06.29

The USAF locks ties into an existing hydropower dam owned by Xcel Energy (the successor to Northern States Power – NSP). The visitor center is currently outgranted to the National Park Service. Additional outgrants are to the Minneapolis Park and Recreation Board (2), one to the Hennepin County Sheriff for mooring of a boat, and one to the Minnesota DOT for a storm sewer drain. The Park and Recreation Board has two, rather extensive, outgrants as part of their urban park plan for Minneapolis, for bike and pedestrian paths, fencing, and landscaping.

Table 2 – USAF Project Lands

Estate	Hennepin County
Fee simple	6.83
Flowage Easement	1.75
Access Road Easment	0.25
Water and Sewer Lines Easement	0.18
Security Fence and Danger Sign	0
Power Transmission Line Easement	0.0001

Table 3 – USAF Outgrants						
Project Outgrants			**Upper Saint Anthony Falls**			
Grantee	Out Grant Type	Description	Ac	Effective Date	Expiration Date	Term
City of Minneapolis Park and Recreation Board	Easement	Right of Way for bike and pedestrian path	1	28-May-1997		perpetual
City of Minneapolis Park and Recreation Board	Easement	Right of Way for bike and pedestrian path, fencing, and landscaping	2.888	30-Nov-1999		perpetual
Minnesota DOT	Easement	Right of Way storm sewer drain (underground)	0.2	16-Jan-1978	15-Jan-2028	50 yrs
US National Park Service	Permit	Education: License to take over tours at observation deck	0.1	20-May-2016	19-May-2021	5 yrs

Lower St. Anthony Falls Lock & Dam (LSAF)

Lower Saint Anthony Falls (LSAF) land interests are comprised of 5.63 acres of fee and 0.80 acres of easements. The easements are a mix of access and utilities. The LSAF dam ties into an embankment to the north of the dam, which is owned by Brookfield Power. All lands were acquired in Hennepin County, Minnesota. Fee lands for LSAF were acquired from multiple owners. The majority of the tracts for both USAF and LSAF are located at the lock sites. Dredged material disposal areas were originally acquired in fee downstream of LSAF. They exceeded their useful life and the City has provided temporary storage areas as needed.

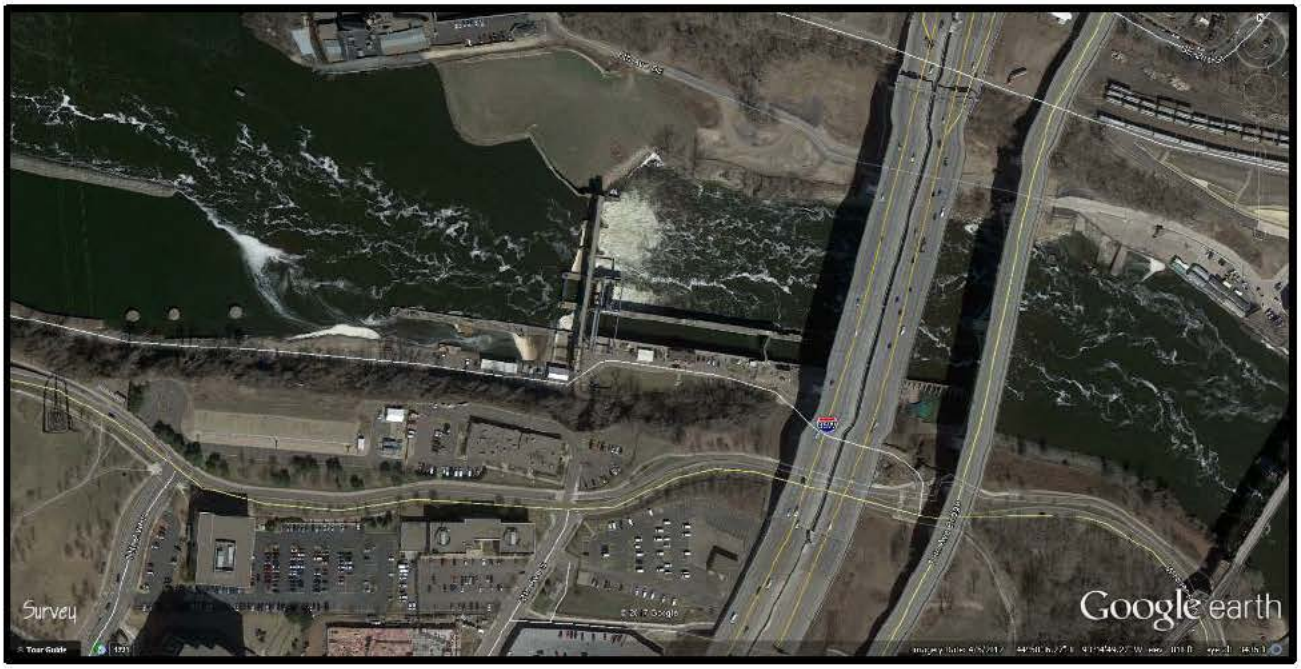

Figure 21 - Aerial View of LSAF, Google Earth image date 4/5/2017

Table 4 – LSAF Project Lands	
Estate	Hennepin County
Fee simple	5.63
Access Road Easment	0.8
Water and Sewer Lines Easement	0

Inventoried Real Property includes the lower lock, central control station, the dam (not including the hydropower plant), shop building,storage building, paved road control stands and light standards.

Figure 22 - LSAF central control building and shop building, lock chamber visible; image date – 2017.06.29

Table 5 – LSAF Project Improvements

	Project Improvements	**Lower Saint Anthony Falls**		
USACE Asset No.	Improvement Description	Location	Year Constructed	Cost
SAF-10623	Lower Lock with Central Control Station	Project Area	1956	10,587,023.29
SAF-10624	Lower Dam	Project Area	1959	7,528,454.23
SAF-28409	Shop Building	Project Area	2009	156,000.00
SAF-10161	Storage Building	Project Area	1958	-
SAF-23364	Light Standards at Lock (17)	Project Area	2003	57,005.00

Table 6 – LSAF Outgrants						
Project Outgrants			**Lower Saint Anthony Falls**			
Grantee	Out Grant Type	Description	Ac	Effective Date	Expiration Date	Term
Xcel Energy	Easement	Electric Transmission Line	0.09	28-Aug-2004	27-Aug-2054	50 yrs
City of Minneapolis Park and Recreation Board	Easement	Right of Way for bike and pedestrian path, fencing, and landscaping	2.888	30-Nov-1999		perpetual
Minnesota DOT	Easement	Right of Way Interstate 35W piers	0.3	22-Jul-1963		perpetual
Minnesota DOT	Easement	Right of Way storm drainage line (underground)	0.08	25-Jan-1963		perpetual
Padelford Packet Boat Company	License	Recr, Comm Non-routine shoreline mooring license	0.1	1-Apr-2012	31-Mar-2017	5 yrs

Lock & Dam 1 (L&D1)

Lock and Dam 1 land interests are comprised of 32.8 acres of fee, at the lock and dam site, and 234.48 acres of easement. The easements are primarily flowage, extending from the lock and dam upstream to Lower Saint Anthony Falls, a distance of 5.8 river miles. Acquisition of tracts began in 1895 and continued until 1999. The majority of the tracts were purchased before 1923. The tracts purchased between 1895 and March 3, 1899 were purchased for the first Lock and Dam 2. This facility was located between Saint Anthony Falls and Lock and Dam 1. It was abandoned before being put into operation and the lock and dam moved downstream so that a hydropower facility could be combined with the federal facility.

Table 7 – Lock and Dam 1 Project Lands

Estate	Hennepin County	Ramsey County	Total
Fee Simple	23.75	9.05	32.8
Easement	177.52	56.96	234.48

Easements acquired for the first Lock and Dam 2 were repurposed for Lock and Dam 1. Lands for Lock and Dam 1 are located in both Hennepin and Ramsey Counties. Just above the Lake Street and Marshall Ave Bridge, Hennepin County is on both sides of the river. Below that point, the right descending bank of the river is in Hennepin County and the left descending bank of the river is in Ramsey County. Although surrounded by cities, Lock and Dam 1 sits in a river gorge. Development is confined primarily to the bluffs and not along the river shoreline. This creates a very natural setting in the heart of the Cities.

Figure 23 - Aerial View of L&D1, Google Earth Image Date 4/5/2017

Inventoried Real Property at Lock and Dam 1 includes the Ambursen Dam, locks, central control station, cribwall and other bluff protection, service building, utility storage building, dam entrance building, control stands, viewing platform, parking lots, and paved road.

Figure 24 - Drone photo of improvements at L&D 1, note the cribwall along the bluff, image date unknown

There are 3 outgrants at Lock and Dam 1. The City of Minneapolis Park and Recreation Board has an easement for a recreation trail which ties into Minnehaha Park, there is a license for mooring of an emergency response boat, and the University of Minnesota has a license for testing of invasive species.

Table 8 – Lock and Dam 1 Outgrants

Grantee	Out Grant Type	Description	Ac	Effective Date	Expiration Date	Term
City of Minneapolis Park and Recreation Board	Easement	Recr, Pub Park: Public recreation trail		28-Mar-2008	28-Mar-2018	10 yrs
Minneapolis Emergency Preparedness & Regulatory Services	License	Other: Mpls Emergency response boat mooring	0.01	13-Jun-2011	12-Jun-2016	5 yrs
University of Minnesota	License	Fish-Wildlife: Testing for Invasive Species	0.01	25-Aug-2014	24-Dec-2016	1.5 yrs

Table 9 – Lock and Dam 1 Project Improvements

USACE Asset No.	Improvement Description	Location	Year Constructed	Cost
LD1-10608	Ambursen Dam	Project Area	1964	4,101,120.79
LD1-10607	Lock with Central Control Station, Cribwall Stabilization	Project Area	1964	59,128,154.28
LD1-10646	Bluff Protection	Project Area	1964	1,948,205.00
LD1-10568	Paved Road	Project Area	1964	125,999.00
LD1-10020	Service Building	Project Area	1983	650,000.00
LD1-10019	Dam Entrance Building	Project Area	1983	50,000.00
LD1-10021	Utility Storage Building	Project Area	1983	300,000.00
LD1-10567	Parking Lot	Project Area	1964	-

Figure 25 - L&D1, looking upriver. The Twin Cities (formerly Ford) hydropower plan can be seen on the far right.

FIRST ITERATION REAL ESTATE QUESTIONS

Real Estate Policy Guidance Letter No. 33 – Interim Guidance on Disposition Studies dated September 28, 2016 outlines the questions Real Estate needs to address for the First Iteration. These questions are listed below. Some responses may be addressed with a single lock and dam in mind or with the system as a whole.

Do the real property and improvements have economic or commercial value?

USAF

Yes, there are three power generation companies that have a current or future interest in the property. Xcel currently has a FERC license[1] harnessing the hydropower. Xcel owns the dam and the improvements opposite USAF.

Two additional companies have FERC licenses to conduct a feasibility study, they are Crown Hydro and Symphony Hydro. Symphony Hydro would use the lock chamber for their generation design. Crown Hydro is designing a system that would utilize existing tunnels and caverns from former industry operations along the river. Crown Hydro is less favored by the community as

[1] License # P-2056

their design interferes with the Minneapolis Parks and Recreation plans for a new park development adjacent to the lock and possibly incorporating the lock site..

LSAF

Yes, there is hydroelectric generation equipment owned by Brookfield Renewable Energy under a FERC license[2] in one of the old chambers of the lock.

L&D 1

Yes, there is a hydropower plant with four turbine-generator units. The plant was originally owned by the Ford Motor Company and operated under a FERC license[3], but it was purchased by Brookfield Renewable Energy in 2011.

What is the potential re-use by others, by potential use classification?

USAF

Aside from the hydropower, this lock has two groups vying for re-use. Minneapolis Parks and Recreation has a plan to expand their park and river walks system; its Phase 2 would abut the USACE property on the northwest side.[4] There is a similar vision, although more expansive vision, with a group called Friends of the Lock and Dam, specifically for the lock and dam site itself. This group plans for a "glass-sided observation platform slung over the lock and beside the falls, sloping lawns, concessions, and a beefed-up visitor's center built atop a 280-car parking garage."[5] This project is estimated to cost $45-million dollars.

LSAF

At this time only the existing hydropower use is foreseen at this site.

L&D 1

This site could be used for office space by a State or Local government agency. Redevelopment is possible, but parking is limited, which would deter business development.

Is there potential for re-use of lands to other Federal agencies?

Currently the National Park Service is conducting tours[6] of USAF and have a permit with USACE. While the local representative would like to continue to provide tours, the agency does not have the budget to take over operation and maintenance of the site.
It is not anticipated that another federal agency would have interest in the sites.

In particular, is there potential re-use of the land by HUD?

All three sites are unsuitable for homelessness housing.

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[2] License # P-12451, USACE Outgrant # DACW37-10-0125
[3] License #   , USACE Outgrant # DACW37-3-050083
[4] https://mplsparksfoundation.org/projects/water-works/
[5] https://www.startribune.com/steve-brant/10644486
[6] https://www.nps.gov/miss/planyourvisit/uppestan htm

Is there potential re-use by the State or other local political subdivisions?

Both USAF and L&D 1 have visitor centers designed into their buildings. They are equipped with restrooms, offices, locker rooms and showers, kitchens and display areas. This could make the sites desirable for the State of Minnesota use or the City of Minneapolis to absorb into its park system.
At LSAF it is unlikely that either the state or city would want to utilize the site.

Is there potential re-use by Native American Tribes?

The Native American community has not expressed interest in any of the sites. The community may not be aware of the current disposition study. The project manager intents to notify the Native American communities in future correspondence.

Is there potential re-use by non-profit entities such as land conservatories or water districts?

American Rivers is an organization that works to remove dams from American rivers. This organization is advocating for the removal of the dams in full or partially to restore the rapids that were once running through the Metro area.[7]

There may be more interest by watershed districts or other conservation groups as the study moves forward.

Is there potential for mixed used development scenario by private sector developers?

Yes, there is development opportunities with hydro-power electric generation companies at all three sites.

USAF

There is also redevelopment interest with the Friends of the Lock and Dam. This would be a public/private sector development.

LSAF

Hydro power redevelopment use is likely the only redevelopment option due to existing buildings and limited land space between the river and the bluffs.

L&D 1

L&D 1 has the potential for a redevelopment of some kind, but no current interest in the site, and parking is limited.

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[7] https://www.americanrivers.org/threats-solutions/restoring-damaged-rivers/

DESCRIPTION OF FEDERAL INTEREST IN DISPOSITION

Screening Criteria:

If the current project does currently meet its authorized purpose of commercial navigation, then a screening criteria for the alternatives include selecting an alternative that allows the USACE to eliminate the financial burden.

Eligibility for Disposition

Disposal of United States Property: Disposal of the project LERRD, improvements, and facilities is a viable option and would relieve USACE of unnecessary operation and maintenance costs in addition to liability concerns associated with trespassing and dam safety. If the property and all improvements situated thereon are disposed of in the future and there is no specific legislation directing the disposal, the property would be disposed of in accordance with The Public Buildings, Property, and Works Act of 2002, as amended, (40 U.S.C. § 101, et seq.) and Army Regulations. This Act recodified, revised, and replaced the Federal Property and Administrative Services Act (FPASA) of 1949.

When disposing of federal real estate, the general process is mandated by federal law. The major steps in this process are described below; however, not every property goes through every step of the process.

Excess Property - When a federal agency no longer needs a property to carry out its program responsibilities, it reports this property as "excess" to its needs.

Federal Transfer - GSA first offers excess property to other federal agencies that may have a program need for it. If another federal agency identifies a need, the property can be transferred to that agency.

Surplus Property - If there is no further need for the property within the federal government, the property is determined "surplus" and may be made available for other uses through public benefit conveyances (PBC), including homeless use, negotiated sales, or public sales based on GSA's determination of the property's highest and best use.

Homeless Conveyance - If a property is suitable for homeless use, according to the Department of Housing and Urban Development, we must first consider transferring the property as a homeless conveyance before any other public benefit conveyance can be considered.

Public Benefit Conveyance - As a PBC, the property can be substantially discounted in price (up to 100% reduction in fair market value) if it is used for a specific public use that qualifies for a PBC through a partner federal agency.

Negotiated Sale - GSA can negotiate a sale at appraised fair market value with a state or local government if the property will be used for another public purpose.

Public Sale of Property - If state and local governments or other eligible non-profits do not wish to acquire the property, GSA can dispose of surplus property via a competitive sale to the public, generally through a sealed bid or auction.

PLAN FORMULATION AND EVALUATION

The purpose of this investigation is to provide information necessary to make final recommendations to Congress as to deauthorization of the federally authorized facilities USAF, LSAF, and L/D 1. The final report will provide information necessary to ultimately facilitate the future disposal if deauthorization is approved. The structure of the study will resemble a typical USACE feasibility study. The team is still in the process of collecting the required data to estimate a Benefit Cost Ratio (BCR) for each alternative if applicable. The period of analysis for the disposition study is 50 years.

Problem Statement

USAF, LSAF, and L/D 1 operate as a system providing commercial navigation to the city of Minneapolis. Since the 2015 closure of USAF, commercial navigation has not been able to access the port of Minneapolis. USAF is no longer used for navigation in any capacity; LSAF and L/D 1 have very limited use and the primary users are recreational boaters and commercial passenger river cruise boats. Since the closure of USAF, the city of Minneapolis and other stakeholders have begun planning and designing a new vision for the port area and the USAF areas; as the local vision for the area changes, there is no demand to restart commercial navigation in this waterway. Furthermore, due to the limited lock size of USAF and LSAF, allowing only two barges to lock through at a time, the demand for commercial use and tonnage of cargo has historically been low in this area.

- The overall problem for the USAF, LSAF, and L/D 1 system is that the waterway has very limited use and the USACE remains responsible for these facilitates despite there being minimal USACE Federal interest in repairing, operating or maintaining them.

Opportunities

- Several entities are known to be interested in the future of these sites. The study would identify potential interested parties to facilitate disposal if the facilities are deauthorized.
-

Objectives

The overall goal of the first phase of the Disposition Study is to establish if a Federal interest in the project still exists or no longer exists and that the project remains a candidate for a disposition study. Specific study objectives include:

- Review and document existing conditions of the current Federal navigation project at USAF, LSAF, and L/D 1.
- Forecast and document expected future conditions to determine if forecasted condition demonstrate a need for the project.
- Provide information necessary to make final recommendations to Congress as to deauthorization of USAF, LSAF, and L/D 1.
- Relieve USACE of continued O&M costs and responsibilities and exposure to continued and future liability associated with these facilities.

Constraints

- Avoid impacts to municipal water supply
- Existing hydropower projects and FERC licenses
- Minimize adverse impacts under Section 106 of the National Historic Preservation Act of 1966 (NHPA)

FUTURE WITHOUT-PROJECT CONDITIONS

The future without project conditions for this analysis would be the No Action alternative. The locks and dams would remain in Federal ownership. At this first phase of study, the decision to be made is whether or not to continue to conduct a disposition study. The future without project conditions or No Action alternative would mean that a disposition study is not completed, and the three projects remain in Federal ownership with USACE responsibility for operation and maintenance.

The anticipated future without project condition varies for each site. Based on current local interest in the three sites, the following are the anticipated future without project conditions, assuming the Decision Milestone recommendation is "No Action".

Upper St. Anthony Falls Lock and Dam:

The Minneapolis Parks and Recreation Board and the non-profit group, Friends of the Lock and Dam, have either proposed or are working on conceptual uses for the upper lock, provided that the lock does not re-open for navigation. It is possible that Congress could direct the Corps to re-open the lock to navigation; however, this scenario is unlikely and has very little local or Congressional support. As such, the future without project scenario assumes that USAF will remain closed to navigation, and with no further disposition action it will remain in Corps ownership. The Minneapolis Parks and Recreation Board and Friends of the Lock and Dam conceptual plans expand the recreational opportunities at the site, which would be compatible with continued Corps ownership, allowing for occasional Corps operation of the site for flood damage mitigation. These plans add developments to the current parking area and operations area, and span over the lock chamber, above the area needed for it to pass flood flows. The National Park Conservation Association is working on developing a vision for a more visible presence at USAF for the National Park Service, which oversees the Mississippi National River Recreation Area, which encompasses all three twin cities locks and dams. These visions would be accomplished under a specifically-authorized feasibility study, cost-shared by a local sponsor. Licensing of the Crown or Symphony hydropower projects by the Federal Energy Regulatory Commission (FERC), may also be part of the "no action" scenario. Crown Hydropower has submitted a license amendment application to FERC, to install a 3.4 MW hydroelectric project adjacent to the lock. Symphony Hydropower has been granted a preliminary permit to investigate the feasibility of installing a 3.4 MW hydroelectric project within the lock chamber. Both hydroelectric project proposals would be compatible with continued Corps ownership, allowing for occasional Corps operation of the site for flood damage mitigation.

Lower St. Anthony Falls Lock and Dam:

The no action alternative would include continued operation of the lock under reduced service (10:00 a.m. to 8:00 p.m.) during the navigation season, and continuous operation of the dam gates 24 hours a day, seven days a week. The co-located hydropower plant would continue the

24 hours a day, seven days a week operations, at least until its current license expires in 2056. There are currently no outside proposals for additional uses of this site. The Minneapolis Park and Recreation Board master plan hints at a bike trail through the site. This proposal would affect the Corps' current security procedures at the site, but could accommodated. This proposal could be pursued under a specifically-authorized feasibility study, cost-shared by a local sponsor; or under a lease agreement.

Lock and Dam No. 1:

The no action alternative would include continued operation of the lock under reduced service (10:00 a.m. to 8:00 p.m.) during the navigation season, and continuing public access to the observation area from 10:00 a.m. to 7:00 p.m. The hydropower plant located on the opposite side of the dam from the lock would continue its 24 hours a day, seven days a week operations. The licensed hydropower plant would continue operating, at least until its current FERC license expires in 2034. There are currently no outside proposals for additional uses of this site. The organization, American Rivers, is actively exploring a proposal to remove Lock and Dam 1 with a vision of restoring the Mississippi River gorge to its pre-1900 condition. This proposal is compatible with the disposal alternative, but not the no action alternative, in which the Corps would continue operating the project. Public awareness of the disposition study may yield interest in additional public uses, if the Corps continues to own the site.

ALTERNATIVES DESCRIPTION

Alternative 1 No Action

The most likely condition expected in the future with no modification to the existing project authority. The project would continue to be operated with routine maintenance and occasional major maintenance as required for safety, to meet the authorized project purpose, or to meet flood risk mitigation requirements.

If the No Action Alternative is selected, the Disposition Study will be terminated. Studies of additional opportunities at the sites could not be conducted using disposition funding. However, there may be opportunities in this scenario for a non-Federal entity to work with the Federal government to modify the project authority to include other authorized purposes, such as ecosystem restoration or recreation. This investigation would need to occur under the appropriate authority in a feasibility study or a major rehabilitation study.

Alternative 2 Congressional Deauthorization and Property Disposal Alternative

This alternative would recommend Congressional deauthorization of commercial navigation for USAF, LSAF, and L/D 1. Following deauthorization, the sites would likely be disposed to a willing entity. This would require identification of a non-Federal or other Federal entity to take over the ownership of the project and pay for a share of the immediate repair and rehabilitation cost and all future operation, maintenance, repair, restoration and rehabilitation expenses and would incur all other responsibilities, risks and liabilities of the project. Under this alternative, it would be assumed that the Federal Government would be required to repair the facility to a safe and reliable condition before the interested party would be willing to accept the transfer. In addition, future Rivers and Harbors Act or Clean Water Act regulatory requirements will be addressed in this alternative.

ECONOMICS/EVALUATION OF BENEFITS AND COSTS

A summary of the results of the preliminary standard economic evaluation is presented in the following paragraphs for the alternative plans. In general, economic benefits and costs will be calculated using established methodologies and procedures as defined in the Planning Guidance Notebook ER 1105-2-100. To the extent practicable, the economic analysis will evaluate alternative plans based on quantitative metrics, but it is likely that there could also be qualitative benefits for this study. The present value of the O&M cost will be determined and based on an expected economic life of 50 years, current Federal discount rate of 2.875 percent.

Project Benefits

The original authorized purpose of the Minneapolis locks and dams was navigation in the form of commercial barge transportation. Subsequent to this recreation on the Mississippi River navigation system also became an authorized purpose. And while not an officially authorized purpose hydropower facilities have been added to each of the dams so that electrical power production has become an additional benefit provided by the lock and dam projects.

Navigation Benefits – The Minneapolis locks and dams no longer serve the originally authorized purpose of commercial barge transportation. Upper St. Anthony Falls lock, the uppermost lock on the Mississippi River navigation system was ordered to be permanently closed in June 2015. Closure of this lock, prevents any barge traffic from reaching the freight terminals in the Minneapolis harbor. But, although barge traffic is not likely to return in the future, it is important to estimate the magnitude of the economic impact of the lock closure as consideration of disposal of the Federal project proceeds.

Prior to 2015, traffic through the Minneapolis locks averaged 755,834 tons per year (2010-2014). At a per ton cost savings of approximately $4.00, the transportation benefits of hauling this level of freight by barge versus rail/truck is estimated at $3.0 million. This was the primary benefit of the Minneapolis locks and served as an offset to the costs of maintaining their operations.

The city of Minneapolis closed their Upper Harbor in December 2014, leaving only two commercial operators upstream of Upper St. Anthony Falls lock and dam. One operator, Northern Metals Recycling has moved their operations to Becker, Mn. The other operator, Aggregate Industries, is still operating, but has switched to over-the-road transport of its materials. Aggregate Industries has purportedly attempted to file a $2M claim for its increase in operating costs, caused by the closure. Prior to the closure, Aggregate Industries, used the lock nearly every day. In 2015, leading up to the closure, they ran loads twice a day, 7 days a week.

Other Navigation – Other users of the Minneapolis locks are recreational boaters (small power craft, fishing boats, canoes, kayaks, etc), commercial cruise vessels, and other commercial vessels besides tow/barge units. The tables below present the number of recreational and other commercial vessels transiting the Minneapolis locks in recent years (Source: USACE Lock Performance Monitoring System database). Note that USAF lock was closed in June 2015 which affected traffic levels then and since. A large majority of the non-tow commercial vessels are cruise boats operating out of Minneapolis and St. Paul.

Table 10 - Recreational Craft Through Minneapolis Locks

Lock	2011	2012	2013	2014	2015	Pre-Closure Average	2016
LD 1	3,241	2,067	1,385	1,690	2,424	2,161	1943
LSAF	1,650	1,166	706	1,087	1,268	1,175	1154
USAF	2,079	1,088	785	1,475	684	1,222	0

Table 11 - Non-Tow Commercial Vessels Through Minneapolis Locks

Lock	2011	2012	2013	2014	2015	Pre-closure Average	2016
LD 1	137	131	69	77	59	95	95
LSAF	304	8	788	471	697	454	628
USAF	961	0	4	0	0	193	0

Table 12 - Commercial (Tow) Vessels Through Minneapolis Locks

Lock	2011	2012	2013	2014	2015*	Pre-closure Average	2016
LD 1	-	620	605	568	254	512	11
LSAF	-	618	592	557	202	492	0
USAF	-	629	596	549	207	495	0
* The 2015 navigation season at Upper St. Anthony Falls ended on 9 June 2015.							

Hydropower Benefits – Each of the three lock and dam projects has a hydropower facility attached to it. Xcel Energy has a plant at Hennepin Island along the USAF dam alignment and Brookfield has one at the LSAF lock and at Lock and Dam No. 1. The Xcel plant has produced an average of 76,244 megawatt-hours (mwh) per year (2008 – 2012 average). Brookfield's LSAF facility has an annual capacity of 63,000 mwh and their plant at LD 1 has produced an average of 93,738 mwh. Applying the regional retail price of $97.29 per mwh, the annual power produced at the Xcel plant is valued at $7.42 million, at the LSAF facility it is valued at $6.13

million, and at LD 1 it is valued at $9.12 million. Total value of hydropower produced at the three locations amounts to $22.67 million per year.

The hydropower benefit may continue regardless of whether or not the Corps disposes of the Federal projects. "Disposal" does not necessarily construe "dam removal".

Project Costs

St. Paul District estimates the annual cost of operating Upper St. Anthony Falls for flood risk management, and the annual cost of operating Lower St. Anthony Falls and lock and Dam 1 to be similar to the costs incurred in 2016, the first full year after closure of the USAF site. These costs are based on level-of-service at Lower St. Anthony Falls and Lock and Dam 1 is assumed to be Level 3, which corresponds to 10-hour-a-day service, 7 days a week during the navigation season. All three Twin Cities locks and dams are overseen by one Lockmaster, whose duty station is assumed to be located at Lower St. Anthony Falls Lock and Dam. The following table contains the estimated future annual operating costs at each of the three twin cities locks.

Table 13 - Average Annual Operating Costs

Location	FY15 operating cost	FY 16 Operating Costs	Assumed Future Operating Costs
Upper St. Anthony Falls	$401,000	$148,000	$148,000
Lower St. Anthony Falls	$927,000	$889,000	$889,000
Lock and Dam 1	$620,000	$445,000	$445,000
Subtotal	$1,948,000	$1,482,000*	$1,482,000
* All three sites are currently tracked as under one project in P2. Cost allocations are assumed at 10% USAF, 60% LSAF and 30% L/D 1.			

In addition to operating costs, there are additional costs for dredging in the pools above Upper St. Anthony Falls and Lock and Dam 1.

Since navigation through the Upper Lock is not allowed, subsequent to WRRDA 2014, no dredging will occur in the pool above Upper St. Anthony Falls. Dredging in pool 1 will be a lower priority, as few, if any commercial towboats have reason to transit Lock 1 or Lower St. Anthony Falls lock. The current channel markers, which are set by the U.S. Coast Guard after the Corps dredges the channel, will become unreliable for 9-foot navigation. For this analysis, it is assumed that future dredging will only be performed in Pool 1, as no commercial navigation is possible above Upper St. Anthony Falls.

Table 14 - Average Annual Dredging Costs			
Location	Average dredging quantity (cubic yards)	Current avg cost @ $9/cy	Assumed Future Annual Dredging Cost
Upper St. Anthony Falls	43,000	$387,000	$0
Lower St. Anthony Falls	-	$0	$0
Lock and Dam 1	33,000	$293,000	$293,000

In addition to normal operating costs, occasional major maintenance will have to be performed at each site to fulfil its current authorized purposes. Lock and Dam 1 underwent several major maintenance improvements between 1979 and 2002 at a cost of approximately $22M. Due to their relatively younger age (opened to navigation in 1963), Upper St. Anthony Falls lock and dam and Lower St. Anthony Falls lock and dam have not yet had to undergo similar major maintenance measures. However, as is the nature of lock and dam structures, major maintenance for the St. Anthony Falls locks and dams eventually will be necessary to maintain reliable service.

Table 15 - Average Annual Major Maintenance Costs			
Location	Major Maintenance cost	Present Value	Annualized Major Maintenance Costs
Upper St. Anthony Falls	Assume $11M - 20 years from now	$6.2M	$237,000
Lower St. Anthony Falls	Assume $44M - 20 years from now	$25.0M	$947,000
Lock and Dam 1	Assume $22M - 40 years from now	$7.1M	$269,000
Subtotal		$38.3M	$1,453,000

Each site receives free electricity from the appurtenant hydropower facilities, as required by their individual FERC licenses (USAF, license No. 2056. LSAF, license No. 11251. L/D 1, license No. 362). While not a direct cost to the Corps, the annual value of this electricity is as follows:

Table 16 - Average Annual Electrical Costs		
Location	Value of Annual Electrical cost	Assumed Annual Future Electrical Costs
Upper St. Anthony Falls (pre-closure)*	$27,000	$27,000
Lower St. Anthony Falls (2016)	$70,000	$70,000
Lock and Dam 1 (2016)	$48,000	$48,000
Subtotal	$145,000	$145,000
* Information for USAF not available for current period. The pre-closure average usage at USAF was 418,000 KwH. The USAF estimate was arrived at assuming the post-closure usage would be half the pre-closure usage, or 209,000 KwH, and applying the current rate of $0.13 per KwH.		

The potential annual savings to the Nation, if the Corps were to dispose of the three locks is $3,373,000. The cost of continuing to operate USAF is $412,000 per year. The cost of continuing to operate LSAF is $1,906,000 per year. And the cost of continuing to operate Lock and Dam 1 is $1,055,000 per year.

Table 17 - Total Average Annual Costs	
Location	Total Assumed Future Annual Costs
Upper St. Anthony Falls	$ 412,000
Lower St. Anthony Falls	$1,906,000
Lock and Dam 1	$1,055,000
Total	$3,373,000

The Present Value of these annual costs is $88,879,000 using a 50-year project life and an annual interest rate of 2-7/8 percent.

This amount would be offset by the annuitized cost to the Government of any repairs that would need to be performed prior to the disposal of the facilities. The potential annual savings from a National Economic Development standpoint would be offset by the annual expense to continue to maintain the site by a non-Federal sponsor, and the cost to users of the loss of the services that the facilities provide. There were a total of 868 lockages at LSAF in 2016. There were a total of

935 lockages at Lock and Dam 1 in 2016. These annual cost savings would be enhanced by the net annual benefits of other potential uses of the facilities.

It is recommended that the next iteration of planning this Section 216 study include a full economic analysis, including examination of all National Economic Development (NED) benefits and costs. The analysis should quantify the cost of operations, maintenance, repair, replacement and rehabilitation; and an assessment of social, environmental, economic and recreational costs and benefits.

COMPARISON OF ALTERNATIVES

The tables in the previous section summarize the costs of continuing operation and maintenance under the No-Action alternative. The annual cost of continuing to operate and maintain USAF is $412,000 with little economic benefit resulting from Corps ownership. The "No Action" alternative results in a BCR of zero and negative excess benefits.

The annual cost of continuing to operate and maintain LSAF is $1,906,000 with little economic benefit resulting from Corps ownership. The "No Action" alternative results in a BCR of zero and negative excess benefits.

The annual cost of continuing to operate and maintain Lock and Dam 1 is $1,055,000 with little economic benefit resulting from Corps ownership. The "No Action" alternative results in a BCR of zero and negative excess benefits.

Alternative 2 (Deauthorization and Disposal) assumes a benefit to the nation by eliminating the yearly O&M cost through the disposal process. However, this results in a BCR value of "N/A" based on the lack of related cost and NED benefit data. There are real estate costs that will be annualized, but those values would be determined in the next phase of study. Currently, Alternative 2 (Disposal) would be the recommended plan even though it does not provide NED benefits. It is, however, the most viable alternative since it allows O&M cost to be foregone, eliminating a financial burden to the nation.

As previously mentioned, at the time of this initial analysis, any overhead or real estate related cost that would be incurred during disposal execution is unknown. Those costs and updated results will be included in the final economic analysis included in the next phase of study.

DESCRIPTION OF RECOMMENDED PLAN

The recommendations for each site will be determined, with Vertical Team concurrence, at the 16 August 2017 Decision Meeting.

The Project Delivery Team (PDT) recommendations for each of the sites are as follows:

Upper St. Anthony Falls Lock and Dam:

Proceed with the Disposition Study. The PDT has determined there is no federal interest in retaining the project for its authorized purpose. The recommendation is to proceed with project deauthorization and disposal following the process described in Chapter 6. It is likely, after going through the procedure for priority of ownership, that the outcome of the study will be a negotiated sale to Xcel Energy, the hydropower operator and owner of the rest of the dam.

Lower St. Anthony Falls Lock and Dam:

Proceed with the Disposition Study. The PDT has determined there is no federal interest in retaining the project for its authorized purpose. The recommendation is to proceed with project deauthorization and disposal following the process described in Chapter 6. It is likely, after going through the procedure for priority of ownership, that the outcome of the study will be a negotiated sale to Brookfield Renewable Energy, the hydropower operator at the site.

Lock and Dam No. 1:

Proceed with the Disposition Study. The PDT has determined there is no federal interest in retaining the project for its authorized purpose. The recommendation is to proceed with project deauthorization and disposal following the process described in Chapter 6. It is likely, after going through the procedure for priority of ownership, that the outcome of the study will be a negotiated sale to Brookfield Renewable Energy, the hydropower operator at the site.

ENVIRONMENTAL EFFECTS

A detailed National Environmental Policy Act (NEPA) document will be conducted during phase II of the study to identify environmental effects of alternatives. This is likely to be in the form of an Environmental Assessment (EA). If, however, potential environmental impacts are determined to be significant during this phase, then an Environmental Impact Statement (EIS) will be conducted. The EA or EIS will disclose any environmental effects that would be caused by divesting of the project. Coordination is expected among resource agencies as the study progresses in accordance with the Fish and Wildlife Coordination Act.

ECONOMIC EFFECTS

An initial economic analysis was performed to determine the NED benefits of divesting of the project. A more detailed NED analysis will be conducted during phase II of the study. In addition, the socioeconomic effects of alternatives will be addressed in the NEPA document.

OTHER SOCIAL EFFECTS

Other social effects, if any, will be determined during phase II of the study and will be addressed in the NEPA document.

SAFETY EFFECTS

A safety inspection will be performed during the next phase, if the decision is to proceed with a disposition study. The safety inspection will evaluate the risk of each alternative, so that full disclosure may be provided to the new owner at the time of disposal. This safety assessment will be for operational safety, rather than dam safety.

CULTURAL RESOURCES

Historic Significance

LD 1 (RA-SPC-5624/HE-MPC-4712), LSAF (HE-MPC-0285/0288) and USAF (HE-MPC-0177) are eligible for listing on the National Register of Historic Places (NRHP). Each facility meets two National Register criteria: Criterion A in the areas of Commerce, Industry, Maritime History and Transportation; and Criterion C in the area of Engineering. All three structures are significant for their association with the UMR Nine-Foot Navigation Project, determined eligible for listing on the NRHP in 1992, with the period of significance from 1931-1948. The USAF is significant for its association with and location within the St. Anthony Falls Historic District, established in 1971, with the period of significance from 1854-1941. In addition, the Falls of St. Anthony are an important and significant area for various Native American groups.

Cultural Resources Laws and Regulations

A variety of Federal preservation laws, Executive Orders and Corps regulations requires the Corps to consider the effects of an undertaking on historic properties. The primary Federal law is the National Historic Preservation Act of 1966 (Public Law [PL] 89-665 as amended by PL 96-515; PL 113-287) under Section 106 (54 USC § 306108) and Section 111 (54 USC § 306121et seq.) and the implementing regulations under 36 CFR 800. Corps regulations and policies also address historic preservation requirements under Project Operations, Environmental Stewardship Operations and Maintenance Policies (ER 1130-2-540). The Real Estate Handbook, Disposal of Real Property (ER 405-1-12) addresses disposal of properties with historic significance. Recreation Operations and Maintenance Policies (ER-1130-2-550) provide policies for public interpretation of Corps projects.

Discussion

All three Twin Cities locks and dams are eligible for listing on the National Register of Historic Places. Upper St. Anthony Falls is located within the St. Anthony Falls historic district. Lock and Dam 1 is located adjacent to two historic districts. All three locks and dams are associated with the authorized 9-foot channel and Lock and Dam 1 is associated with the authorized 6-foot channel. LSAF is adjacent to the St. Anthony Falls Historic District. Effects of alternatives will be addressed in the NEPA document. USAF and L/D 1 in particular, would offer a variety of opportunities for public interpretation of cultural resources, in accordance with ER 1130-2-550. USAF has a visitor center with interpretive displays in an around the facility. Prior to closure, Corps rangers staffed the visitor center and provided tours. Tours are now run by the National Park Service under an agreement with the Corps. L/D 1 has interpretive panels in and around the facility and includes a self-guided tour. Occasionally, Corps rangers conducted tours at L/D 1. With the closure of USAF, Corps rangers no longer staff these facilities. USAF and L/D 1 were the only locations in MVP with uniformed rangers on the Upper Mississippi River presenting interpretive outreach programs (e.g. regional and national history and Corps missions) and Corps water safety initiatives to urban audiences.

No Action Alternative

Under a No Action Alternative, the Corps would continue to operate the facility and conduct historic preservation reviews as needed.

Disposition Alternative

Under a disposal alternative, a variety of historic preservation measures would be required to ensure that long-term preservation of the facilities historic significance are retained or adverse effects mitigated for. This may entail the development of adequate legally enforceable restrictions or conditions for transfer, lease or sale of the properties (36CFR§800.5; 36CFR§800.6). Such agreements and mitigation measures would be developed in consultation with the Minnesota State Historic Preservation Office, the Advisory Council on Historic Preservation, various Native American groups and other germane agencies (e.g., the Federal Energy Regulatory Commission, local historic preservation boards, etc.), interest groups and the public.

Other historic preservation activities would potentially include Phase I surveys to identify archaeological sites in undisturbed areas on the properties and Phase II evaluations for properties identified and documentation of existing historic structures. Additional documentation may include Historic American Buildings Surveys, development of Historic American Engineering Records, Historic American Landscapes Surveys and the formulation of various public education documents and programs.

KEY UNCERTAINTIES

The key uncertainties with this investigation include the following:

- Steps to overcome adverse effects under Section 106 because the locks and dams are eligible for listing on the NRHP
- Public acceptance
- Potential to classify projects as reservoirs if projects remain in Corps ownership
- Existing hydropower projects and FERC license at each site
- The role of these locks and dams in deterring the range expansion of Asian carp and other aquatic invasive species

ENVIRONMENTAL COMPLIANCE AND MITIGATION REQUIREMENTS

As mentioned above, all NEPA documentation and Section 106 coordination will be completed during phase II of this analysis once approval has been given to continue the study.

Compliance with other environmental laws, regulations, and executive orders will also be addressed during phase II. Compensatory mitigation is not expected, but that will be determined during the NEPA process as well.

Table 18. Laws, Regulations, and Executive Orders Applicable to the Disposition Study.
Bald and Golden Eagle Protection Act, 42 USC 4151-4157
Clean Air Act, 42 USC 7401-7542
Clean Water Act, 33 USC 1251-1375
Comprehensive Environmental Response, Compensation, and Liability Act, 42 USC 9601-9675
Endangered Species Act, 16 USC 1531-1543
Farmland Protection Policy Act, 7 USC 4201-4208
Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (EO 12898)
Federal Water Project Recreation Act, 16 U.S.C. 460-1(12), et seq.
Fish and Wildlife Coordination Act, 16 USC 661-666c
Floodplain Management (EO 11988 as amended by EO 12148)
Food Security Act of 1985, 7 USC varies
Invasive Species (EO 13112)
Land and Water Conservation Fund Act, 16 USC 460d-461
Migratory Bird Treaty Act of 1918, 16 USC 703-712
National Environmental Policy Act, 42 USC 4321-4347
National Economic Development (NED) Plan
National Historic Preservation Act, 54 USC 3001, et seq.
Noise Control Act, 42 USC 7591-7642
Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities (EO 11282 as amended by EO’s 11288 and 11507)
Protection and Enhancement of the Cultural Environment (EO 11593)
Protection of Wetlands (EO 11990 as amended by EO 12608)
Protection and Enhancement of Environmental Quality (EO 11991)
Protection of Migratory Birds (EO 13186)
Resource Conservation and Recovery Act, 42 USC 6901-6987
Rivers and Harbors Act, 33 USC 401-413
Water Resources Development Acts of 1986, 1990, 2000, 2007, and 2014
Wild and Scenic Rivers Act, 16 U.S.C. 1271, et seq.

DESCRIPTION OF INTERESTED PARTIES AND STAKEHOLDERS

There are several entities who might be logical sponsors for redevelopment or new owners of the projects.

The original local sponsor for the Upper and Lower St. Anthony Falls project was the city of Minneapolis. The city of Minneapolis provided cost-sharing in the amount of $1,100,000 in cash, plus relocation of bridges, provision of lands for the project construction, in addition to dredged material disposal sites for future channel maintenance. The lands for the project were purchased by the Government directly from Northern States Power. As the original sponsor, the City of Minneapolis may have some rights if transfer of ownership is the recommended plan. The purchase agreement with Northern States Power will need to be investigated to determine any buy-back rights. Those inherent rights will be examined early in the process to help guide the formulation of alternatives.

The city of Minneapolis would be a logical sponsor for the reauthorization alternative, in which the Corps would continue to own the site, but additional purposes would be authorized. The city of Minneapolis, through the Minneapolis Parks and Recreation Department, has developed the draft "St. Anthony Falls Regional Park" master plan, which envisions some public access to and use of the lock and dam facilities. This indicates that the City may be interested in new uses for the site.

A non-profit organization, Friends of the Lock and Dam, was formed in 2016 for the purposes of redeveloping the USAF site for public purposes. The Friends of the Lock and Dam may be able to sponsor a future feasibility study.

Other parties who may have interest in Upper St. Anthony Falls include one of several hydropower license owners; these entities may be potential sponsors for disposition of the site. Xcel Energy and Crown Hydro possess hydropower licenses at Upper St. Anthony Falls. The Xcel license expires in 2034. Another potentially interested party is Symphony Hydropower, which currently possesses a preliminary permit from FERC for development of a small hydropower project in the lock chamber at Upper St. Anthony Falls.

In addition to the city of Minneapolis, Brookfield Renewable Power is another interested party at Lower St. Anthony Falls Lock and Dam. Brookfield Renewable Power possesses a hydropower license at Lower St. Anthony Falls, and has installed facilities within the Corps' structures. A negotiated sale to Brookfield Renewable Power could be discussed when the hydropower license renewal comes due in 2056.

The Lock and Dam 1 project was constructed entirely with Federal funds. The dam included the foundations for a hydropower plant on the left bank of the river. The hydropower owner constructed its own facilities, but compensates the Federal government for use by providing free power to Lock and Dam 1. Brookfield Renewable Power possesses the hydropower license at Lock and Dam 1 and would have an interest in its future disposition. A negotiated sale to Brookfield Renewable Power could be discussed when the hydropower license renewal comes due in 2034.

In addition to these interested parties, all three Twin Cities locks and dams lie within the National Park Service's Mississippi National River Recreation Area, and the National Park

Service may be able to partner in a feasibility study, but does not currently have the funding for full ownership of the facilities.

The following is a list of all known stakeholders and potential future owners:

City of Minneapolis: (Potential future owner). Original sponsor for the building the lock project. Contributed $1.1 million in cash, any required alterations in highway bridges, lands, easements/rights-of-way, and spoil disposal areas for new work and future maintenance. Minneapolis will be concerned about access for 3rd Avenue bridge repairs and access for emergencies and future use of the site. The city will also be concerned with maintaining the upper pool, as it affects the city's water supply intakes.

Minneapolis Water Patrol and Hennepin County water Patrol: Both access sites for the purpose of water rescues.

Sen. Amy Klobuchar: Key author of the bill to close the USAF.

Rep. Betty McCollum: Congressional member.

Rep. Keith Ellison: Congressional member. Supports closing all three locks.

Minneapolis Parks and Recreation Department, or MPRB: (Potential future owner).Currently planning two park-related plans encompassing or adjacent to Upper St. Anthony Falls Lock and Dam: the St. Anthony Falls Recreation Area and Water Works Park. The MPRB is opposed to any development by Crown Hydropower or any other development which would impact park lands.

Friends of the Lock and Dam: (Potential future owner).Non-profit formed in 2016 for the purpose of fund-raising and building support for redevelopment of the USAF lock.

Minnesota Department of Natural Resources: Funds Asian carp studies.

U.S. Fish and Wildlife Service: Agency designated as the federal lead on Asian carp.

National Park Service: (Potential future partner).Stewards of the Mississippi National River and Recreation Area (MNRRA), which includes 72 miles of the Mississippi River and four miles of the Minnesota River and encompasses about 54,000 acres of public and private land and water in five Minnesota counties, stretching from the cities of Dayton and Ramsey to just south of Hastings, Minnesota. Supports prevention of the spread of Asian carp. Would like to increase the public's contact with the Mississippi River at USAF.

National Parks Conservation Association: An independent, membership-based organization devoted exclusively to advocacy on behalf of the National Parks System. Its mission is "to protect and enhance America's National Park System for present and future generations."

U.S. Coast Guard: General interest in any issue which impacts navigation safety.

Stop Carp Coalition: Environmental interest group dedicated to stopping the spread of Asian carp.

American Rivers: (Potential future owner).Proponent of the Restore the Gorge initiative, which is exploring local interest in removing Lock and Dam 1.

Longfellow Community Council: Local community group interested in stopping the spread of Asian Carp above Lock and Dam 1. Co-proponent of the Restore the Gorge initiative.

Paradise Charter Cruises: Operates out of Bohemian Flats downstream of Lower St. Anthony Falls Lock and Dam. Affected by the decreased level of service at Lower St. Anthony Falls Lock and would be affected by removal of Lock and Dam 1.

Recreational Boaters: All recreational boaters were affected by the closure of USAF and the reduced level of service at Lower St. Anthony Falls Lock and Dam and Lock and Dam 1.

Minneapolis, St. Paul and University of Minnesota rowing clubs: use the pool of lock and dam 1 for from March through October of each year for training. Are opposed to the removal of lock and dam 1.

Native American Tribes: Are interested in any proposals regarding the Mississippi River in this area.

Xcel Energy (USAF Hydropower): (Potential future owner). Hydropower operations were not affected USAF closure, but their FERC license ties them to the flow capacity through the lock. Owns the spillway and horseshoe dam. Flashboards on horseshoe dam keep pool water level high during low-flow periods, which is essential for the Minneapolis water supply. Xcel provides free electicity to the Upper lock, as part of their FERC license.

Crown Hydropower: (Potential future owner). Submitted a draft license amendment application to FERC on 30 April 2015 for location of a hydropower project on Corps land at Upper St. Anthony Falls. This application has not been granted. Closure of Upper St. Anthony Falls Lock and Dam to navigation would benefit the hydropower developer, as they will not have to compete as much for the flow needed for hydropower production. They may find an alternate owner less cooperative than the Corps.

Symphony Hydropower: (Potential future owner). Granted a preliminary permit from FERC to develop a hydropower project in the lock chamber at Upper St. Anthony Falls Lock and Dam, located in the lock chamber.

Brookfield Renewable Energy: (Potential future owner).Owns and operates the hydropower facilities at Lower St. Anthony Falls lock and dam and Lock and Dam 1.

Tourists: Use the public viewing areas and visitor facilities deck at Upper St. Anthony Falls Lock and Dam and Lock and Dam 1.

University of Minnesota Aquatic Invasive Species Research Center: Conducting research on swim capabilities and acoustic barriers at lock and dam 1, 2, 4, 5 and 8.

Minnesota State Historic Preservation Office (SHPO): Interested in all aspects of the St. Anthony Falls historic district.

POTENTIAL PROJECT SPONSORS

There are parties that are interested in the future of the three locks and dams, regardless of whether or not the Corps continues to operate and maintain them.

If "No Action" is the selected alternative, the City of Minneapolis, Minneapolis Park and Recreation, Friends of the Lock and Dam, National Park Conservation Association, and the National Park Service would be likely candidates to partnering with the Corps in a feasibility study for future beneficial use of Upper St. Anthony Falls, or Lock and Dam 1. Lower St. Anthony Falls lock and dam is not suitable for expanded public use, but may be for expanded hydropower use.

If "Deauthorize and Disposal" is the selected alternative, the City of Minneapolis, Minneapolis Park and Recreation, Friends of the Lock and Dam, National Park Conservation Association, National Park Service, Xcel Energy, Brookfield Power, or American Rivers could potentially be future owners of the sites. The disposal action could be through a negotiated sale to any of the partners, or, if appropriate, sealed bidding or public auction.

CAPABILITY OF THE ENTITY TO ASSUME OWNERSHIP

More information concerning the capability of the entity to assume ownership will be presented at the tentatively selected plan (TSP) level of the analysis, provided the recommended action is to continue with the disposition study.

REQUIREMENTS FOR IMPLEMENTATION OF RECOMMENDATION

Cost and Schedule

If the recommendation is to continue with the disposition study, the project delivery team (PDT) will continue the analysis and work toward the TSP milestone during phase II of the study. The expected cost to reach the TSP milestone is $600,000. The tentative time frame to hold a TSP milestone meeting is September 2018.

OTHER CONSIDERATIONS

All three Twin Cities dams are considered high-hazard, and new owners would need to have the resources to maintain the projects to ensure they continue to act as part of the damming surface and that each project continues to be maintained and operated for flood control, if specified in the individual regulating plans for each site. As with other Corps projects disposal of the project under a negotiated sale may involve completion, by the Corps, of rehabilitation, maintenance work, or other modifications as may be specified in the agreement.

If the recommendation is continued Corps ownership of the projects, the addition of facilities for recreation and fish and wildlife may be able to be undertaken under the authority of Section 4 of the Flood Control Act of 1944, as amended, provided there is a cost-sharing sponsor and the sponsor is willing to fund the cost of operation and maintenance of those facilities. Under this authority, preference is given to Federal, State, or local governmental agencies and is intended for suitable public park and recreational purposes.

This statute, as amended, declares the intent of Congress that recreation and fish and wildlife enhancement be given full consideration as purposes of Federal water development projects if non-Federal public bodies agree to: (1) bear not less than one-half the separable costs allocated for recreational purposes or twenty-five percent of the cost for fish and wildlife enhancement; (2) administer project land and water areas devoted to these purposes; and (3) bear all costs of operation, maintenance and replacement.

It is likely that the Minneapolis Park and Recreation Department, the National Park Service, the Fish and Wildlife Service or the Minnesota Department of Natural Resources would be willing partners in recreational developments at the Upper St. Anthony Falls or Lock and Dam 1 site. It is recommended that these entities be consulted with during the Section 216 study to ascertain their interest and willingness to be partners in any of the alternatives examined in the study.

It is also possible that Brookfield Renewable Power would be a willing sponsor at Lower St. Anthony Falls if it could mean that they could install additional hydropower generating facilities at the site.

Friends of the Lock and Dam has developed plans for future use of Upper St. Anthony Falls lock and dam. This highly-organized group is very effective at fund-raising in generating interest in a key tourist destination in downtown Minneapolis.

RECOMMENDATIONS

It is hereby recommended that funding be provided to continue the Section 216 Disposition study, leading to eventual deauthorization, disposition and disposal of the three twin cities locks and dams. The cost of such a study is typically $1.2M with $600,000 being the estimated cost to reach the Tentatively Selected Plan milestone.

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6. Minneapolis Park and Recreation Board, St. Anthony Falls Regional Park Master Plan, draft 12/04/2014.
7. Water Control Manual, Mississippi River Nine Foot Channel Navigation Project, Saint Anthony Falls, Upper Lock and Lower Lock and Dam, Minneapolis, Minnesota, Appendix SAF of the Master Water Control Manual, updated May 2004.
8. Environmental Compliance Review – Lock and Dam 1 Scour Repairs. U.S. Army Corps of Engineers, St. Paul District. 2015.
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14. Feasibility Study for Mississippi Whitewater Park. Prepared by McLaughlin Water Engineers and John Anderson Architect. 30 June 1999.
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Documentation Report (EDR) that was developed only to the conceptual level needed to estimate the cost of the project to facilitate funding of the project, and to provide information necessary for preparation of an Environmental Assessment. Thus, many of the designs and cost estimates of this Value Engineering (VE) Study and the EDR are preliminary and relative to each alternative. Substantial added design will be required to confirm the economic viability of selected proposals.

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17. Final Feasibility Report and Environmental Assessment - Hydropower (St. Anthony Falls Locks & Dams, Mississippi River). U.S. Army Corps of Engineers, St. Paul District. February 1984.
18. Stability Analysis Lower St. Anthony Falls Lock and Dam Mississippi River Volume 1 of 2. U.S. Army Corps of Engineers, St. Paul District. June 1996. A stability analysis for Lower St Anthony Falls Lock and Dam Mississippi River Vol 1 of 2 Mississippi River, Minnesota, Lower St. Anthony Falls Lock and Dam Stability Analysis Independent Technical Review.
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22. Finding of No Significant Impact re Placement of Steel Sheet Pile for the Rehabilitation of Lock and Dam 1, Minneapolis Minnesota. U.S. Army Corps of Engineers, St. Paul District Aug 1980. Placement of Steel Sheet Pile for the Rehabilitation of Lock and Dam No. 1 Minneapolis Minnesota. The purpose of the proposed project is to place steel

sheetpile adjacent to Lock and Dam No. 1 to control seepage water. The finding of no significant impact is based on the following factors. The material to be excavated consists primarily of material coarser than sand, including gravel, limestone, and concrete fragments; few aquatic or terrestrial organisms are in the project area; and minor or insignificant impacts are expected on aquatic biota and water quality. An assessment of impacts is presented in the attached environmental impact assessment matrix and section 404(b) (1) evaluation

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24. *Periodic Inspection Reports:*
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33. Upper St. Anthony Falls Lock & Dam Mississippi River Periodic Inspection Report No 8. U.S. Army Corps of Engineers, St. Paul District. Feb 2005.
34. Upper St. Anthony Falls Lock & Dam Periodic Inspection Report No. 9. U.S. Army Corps of Engineers, St. Paul District. Jun 2010.
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March 2017 (inspection date June 2015). Periodic inspection and dam safety risk assessment for Upper and Lower St. Anthony Falls locks and dams.

36. Lower St Anthony Falls Lock and Dam Periodic Inspection Report 2. U.S. Army Corps of Engineers, St. Paul District. June 1975.
37. Lower St. Anthony Falls, Mississippi River, Minnesota, Lock and Dam, Periodic Inspection Report 3. U.S. Army Corps of Engineers, St. Paul District. June 1980.
38. Lower St. Anthony Falls Lock & Dam, Dewatering Inspection Report, Periodic Inspection No. 3, Supplement No. 1. U.S. Army Corps of Engineers, St. Paul District. Feb 1983.
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48. Lock and Dam 1 Crib Wall Periodic Inspection Report 2. U.S. Army Corps of Engineers, St. Paul District. Aug 1983.
49. Lock and Dam 1 Periodic Inspection 2. U.S. Army Corps of Engineers, St. Paul District. Sept 1986.
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Upper St. Anthony Falls Lock and Dam, Lower St. Anthony Falls Lock and Dam, and Lock and Dam No. 1
Disposition Study

Focused Questions from 1st Iteration

Decision Meeting August 16 2017

1. Does the project currently meet its authorized purposes?

Response- The primary purpose of the current project is navigation. The Upper St. Anthony Falls (USAF) site does not meet this authorized purpose. Lower St. Anthony Falls (LSAF) and Lock and Dam 1 (L/D 1) partially meet this purpose. The three sites operate as a system, and with the closure of USAF, the ability of the other sites to meet their authorized navigation purpose is compromised. While LSAF and L/D 1 remain open for commercial navigation, use is restricted because USAF is no longer in operation; as such, the system is only partially able to meet its purpose.

Recreation is a secondary purpose; this purpose is being bet with tours at USAF, the visitor center at L/D 1, and with recreational navigation at LSAF and L/D 1.

Flood mitigation is not an authorized purpose, but WRRDA 2014 allows USAF to operate for flood damage mitigation. At USAF gate operator replacement is in process.

2. Is there reason to believe that the future conditions or needs will be different from those present under the current conditions? How so?

Response- There is currently significant recreational use of the project which is expected to continue. The current conditions are expected to continue into the future.

USAF – The City of Minneapolis and Minneapolis Parks and Recreation will continue with their plans to revitalize the Mississippi Riverfront surrounding the lock and dam. A new hydropower development may be licensed by FERC under the objection of the local residents.

LSAF – No change.

L/D 1 – Little change. Additional residential developments in St. Paul will bring more focus to the river gorge. Decreased priority for dredging upstream of the lock will eventually affect the 9-foot channel.

3. Are there opportunities to modify the project to serve a water resources development purpose other than the one for which it was originally authorized?

Response- There is interest by other federal and non-federal parties in recreation and hydropower opportunities at the sites.

USAF – Minneapolis Parks and Recreation and the Friends of the Lock and dam have both developed visions for a revitalized riverfront that include redeveloping the facility for greater public use. The National Park Service would like to utilize the site to enhance recreational opportunities.

LSAF – none.

L/D 1 – Additional recreational opportunities could be added to the site. American Rivers has a proposal to remove the dam and restore the river gorge to a more natural condition.

4. <u>Does the project pose a risk to public safety? What is the project's DSAC, if applicable? Describe the risk, including key risk drivers and uncertainties.</u>

Reponses- Yes. These sites are an attractive hazards located in a densely populated urban area near a large university. USAF has a Dam Safety Action Classification (DSAC) rating of 4, LSAF has a DSAC rating of 5 and L/D 1 has a DSAC rating of 5.

USAF – No permanent staff are at the site. The limited staff at LSAF and L/D 1 monitor the site, but it has already been tagged with graffiti and unauthorized personnel have gained access and been escorted off the site. There is more than a 50-foot fall off the lock wall to the water below, several tripping hazards and turbulent flow over the adjacent spillway.

LSAF – While staff are on site 24/7, the site is inherently dangerous to the public, with more than a 25-foot fall off the lock wall to the water below, tripping hazards and turbulent waters near the dam.

L/D 1 – The site is currently set up for public access to certain areas during the navigation season.

5. <u>Are there environmental concerns or other controversies surrounding the project that will influence the scope and outcome of the study?</u>

Response- Although recreation is not an authorized project purpose, the project is heavily used by the local community for recreation. All three Twin Cities locks and dams are eligible for listing on the National Register of Historic Places. Transferring ownership of these facilities would likely require mitigation under Section 106 of the National Historic Preservation Act of 1966 (NHPA).

USAF – if the issue with the fear of the spread of Asian carp is alleviated, special interests may push to re-open the lock to navigation. If the navigation mission is restored, disposition is not appropriate. This scenario is very unlikely.

LSAF – no concerns.

L/D 1 – there would be no environmental concerns unless disposition involves another entity emoving the dam.

6. Are the real property and improvements associated with the project suitable for public uses other than water resource development? Do the real property and improvements have commercial value?

Response-

USAF – Yes. The Friends of the Lock and Dam have a concept which repurposes the lock structure to include a multi-level parking garage, event space, interpretive space, concessions and public access.

LSAF – Not suitable for public use, except pathway through. The city of Minneapolis has expressed interest in adding a bikeway or other path through this area, this would not include public access to the lock and dam.

L/D 1 – Yes. The space can be repurposed.

All sites - The real property and improvements do have commercial value.

7. Are alterations to improvements likely to be necessary in order to safely dispose of the improvements?

Response-. For all sites, this will depend upon whether or not disposal involves a negotiated sale, or public sale by sealed bid or auction. A negotiated sale may involve rendering the projects safe for public use, or in the case of LSAF, possibly automating the dam gates.

8. What is the annual holding cost and anticipated transaction cost, including any rehabilitation required?

Response- Current annual operations and maintenance costs are listed below:

USAF: $ 590,000

LSAF: $2,629,000

L/D 1: $1,621,000

(Including operations, major maintenance, dredging and electrical usage).

9. What other special considerations or potential liabilities exist due to retaining ownership of the project?

Response-. With low usage, the priority for maintenance funding will be low, compared to other navigation projects, eventually leading to deterioration of the projects and decreasing the safety condition and value of the property. The current management approach is "fix as fails."

10. What is the level of Congressional interest in the project and disposition study, if any?

Response- There is significant Congressional interest in the project and the disposition study. Senators Klobuchar and Franken and Congressman Ellison supported the closure of USAF.

Congressman Ellison is interested in the future of USAF and supports removing L/D 1. Congresswoman McCollum is interested in the future of the sites and supports alternative uses.

11. What uncertainties need reduction in order to make a recommendation?

Response- A recommendation to continue with the disposition study with the intent to ultimately recommend deauthorization and disposal of the project can be made can be made with the current data.

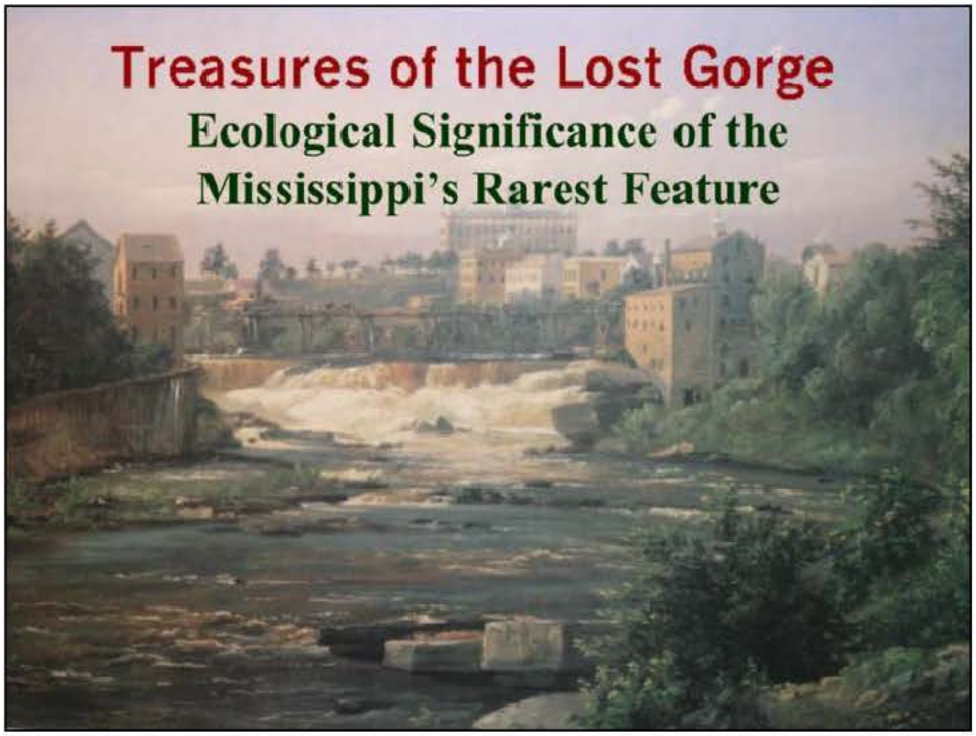
During the next iteration of planning, FERC is currently considering the application for a license amendment for Crown Hydropower to locate a new hydropower project at USAF. FERC has also granted a preliminary permit to Symphony Hydropower for a hydropower development in the lock chamber.
The operations for flood mitigation is a hazy requirement. It is not an authorized purpose, but WRRDA 2014 allows the Corps to operate it for this.

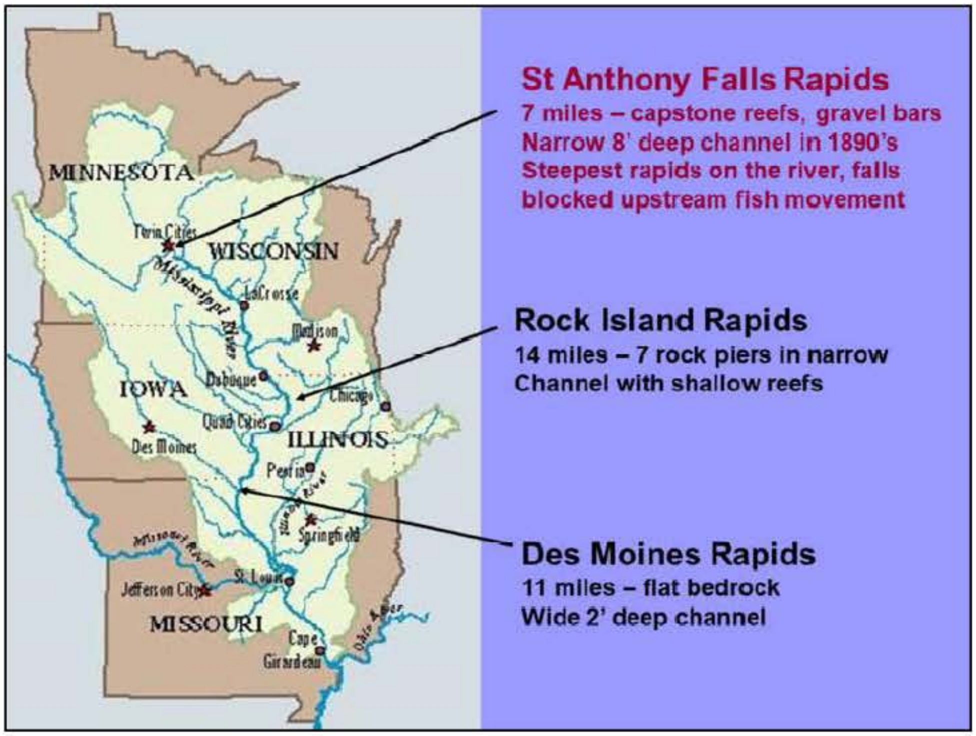
12. Are there issues for the vertical team to monitor and review, which would help to inform the divestiture process?

Response-. The City of Minneapolis, Minneapolis Parks and Recreation, and the Friends of the Lock and Dam are interested redeveloping USAF and are potential partners whether the Corps disposes of or retains the property.

13. Is there evidence that the disposition study should continue?

Response-Yes


Treasures of the Lost Gorge
Ecological Significance of the
Mississippi's Rarest Feature



Of three historic rapids in the Upper Mississippi two were pretty much eliminated for shipping through blasting and dredging or diversion channel, but the St. Anthony rapids still exists beneath the reservoir and is the steepest of all of them; fish can't move beyond due to the falls because it is a barrier to fish movement, as a result fish build in numbers below it as they attempt to continue upstream.

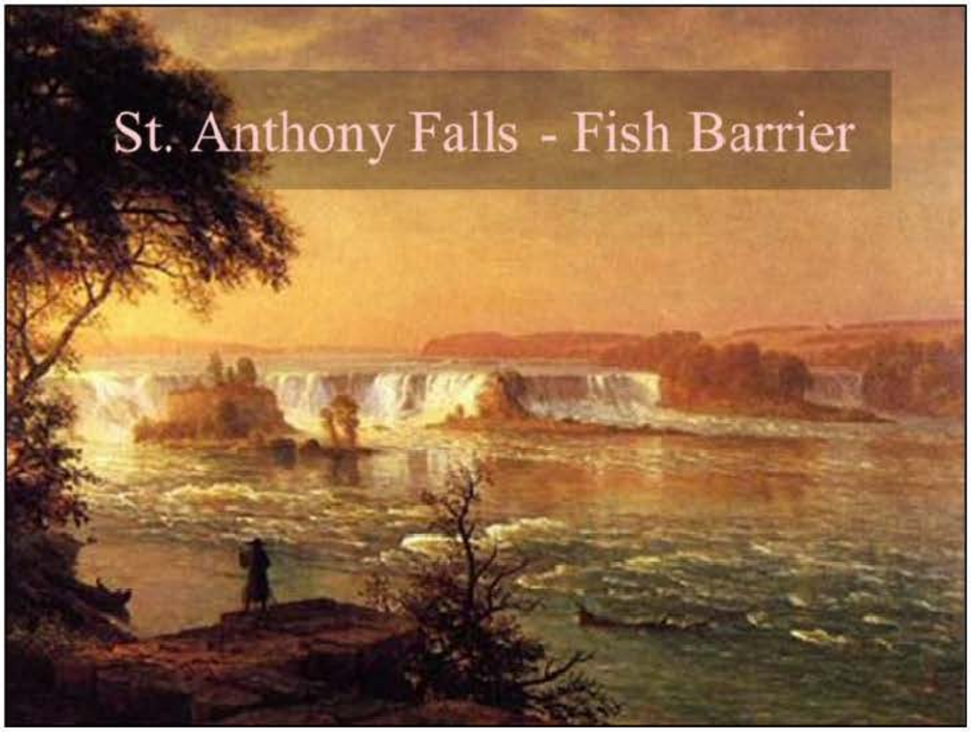
Upper Mississippi River

St. Anthony Falls Rapids and Gorge

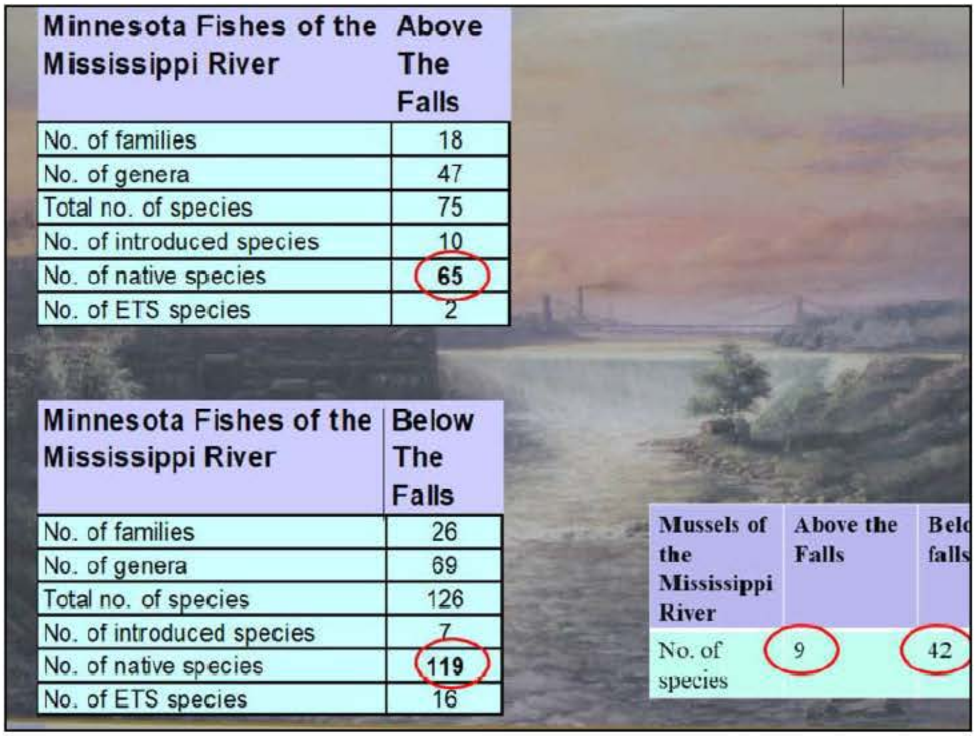
Information from the 1890s Mississippi River Commission Maps

- Gravel, cobbles and boulders dominated the channel bottom substrate.
- Channel width ranged from 450 to 850 feet with at least 13 islands.
- Water surface gradient ranged from > 6.5 ft/mile near the falls to 2.5 ft/mile
- Water depths varied but channel depths were typically 6 – 10 feet deep.

In the 1890's the Mississippi River Commission funded a detailed study of the river that produced very detailed maps showing the river's width, depth, bottom type and shoreline and floodplain plant cover. Transects crossed the river every 1,000 feet. These are some of the highlights within the gorge from that study.



St. Anthony Falls was a barrier to fish movements for thousands of years

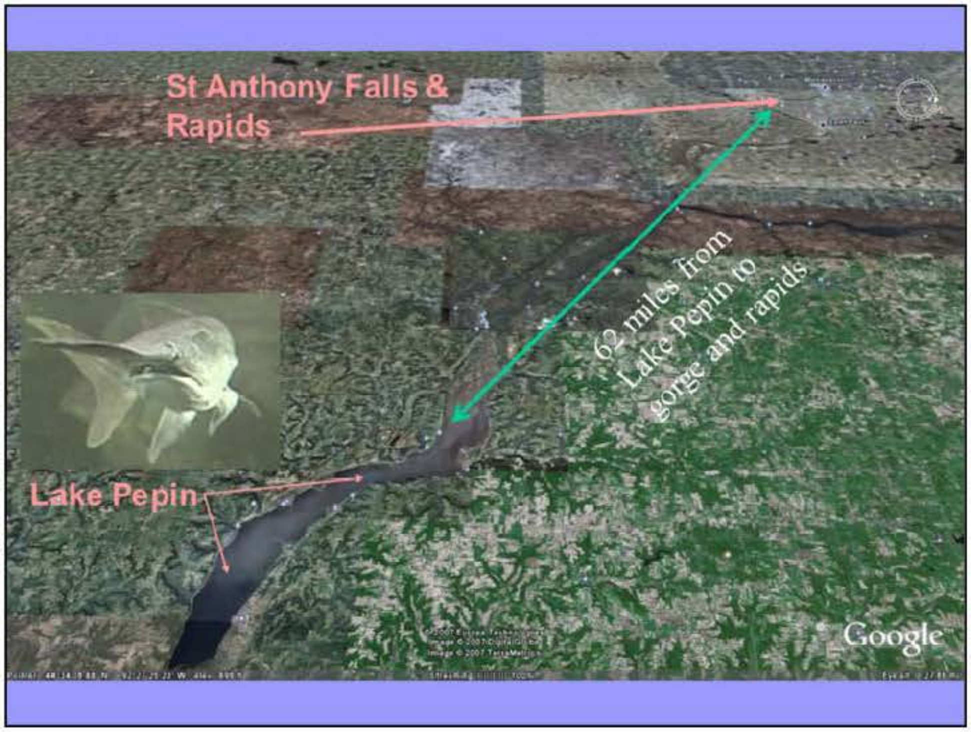


Minnesota Fishes of the Mississippi River	Above The Falls
No. of families	18
No. of genera	47
Total no. of species	75
No. of introduced species	10
No. of native species	**65**
No. of ETS species	2

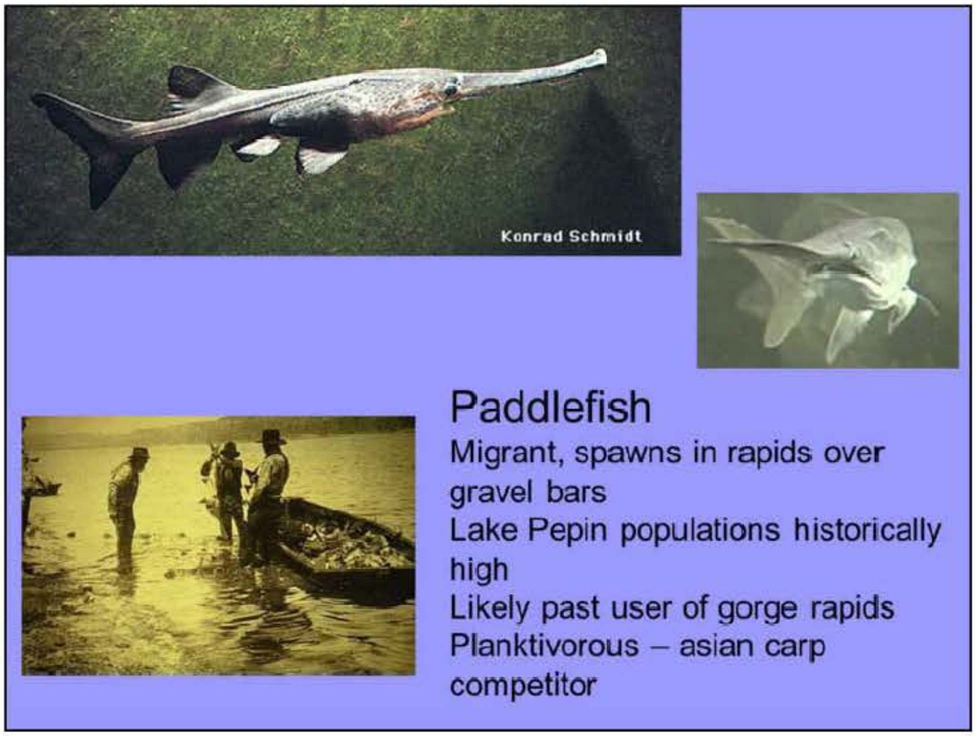
Minnesota Fishes of the Mississippi River	Below The Falls
No. of families	26
No. of genera	69
Total no. of species	126
No. of introduced species	7
No. of native species	**119**
No. of ETS species	16

Mussels of the Mississippi River	Above the Falls	Bel falls
No. of species	9	42

This barrier has resulted in many more fish and mussel species being present below the dam, nearly twice as many fish and 4 times as many mussel species



Lake Pepin is a naturally formed riverine lake about 60 miles downstream of the gorge. Fish such as paddlefish and sturgeon that dwell in the lake must migrate to spawn in rapids.

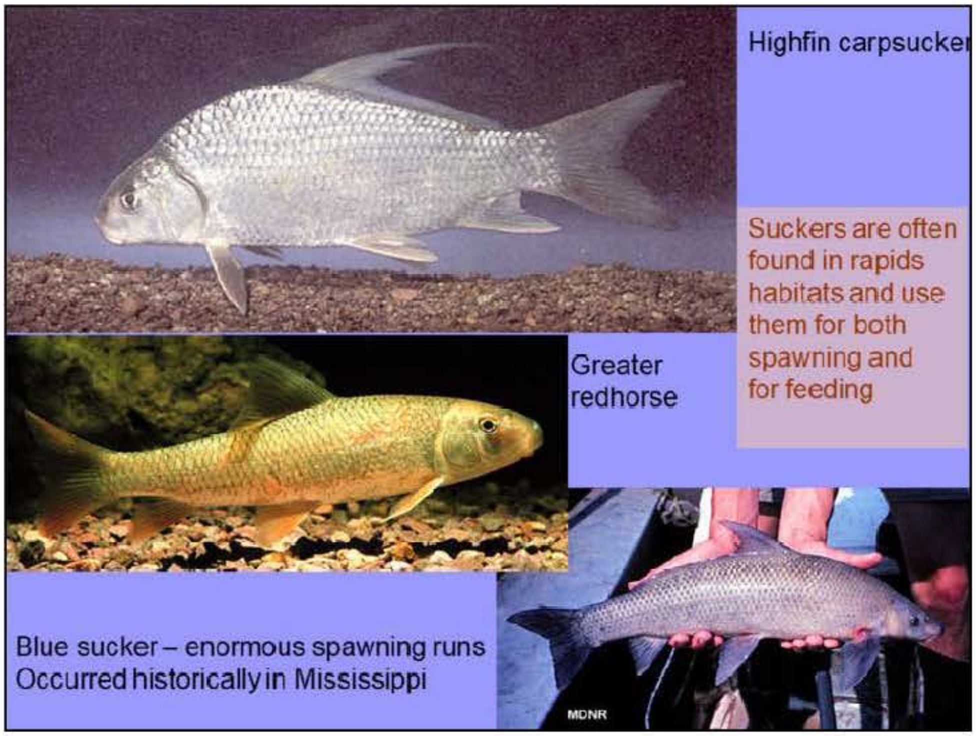


In Lake Pepin's slow moving water great populations of plankton fed a huge population of paddlefish. Paddlefish are plankton feeders, as are bighead and silver carp. These river monster fish grow to more than 100 pounds in size and to reproduce seek out and migrate to rapids habitats.

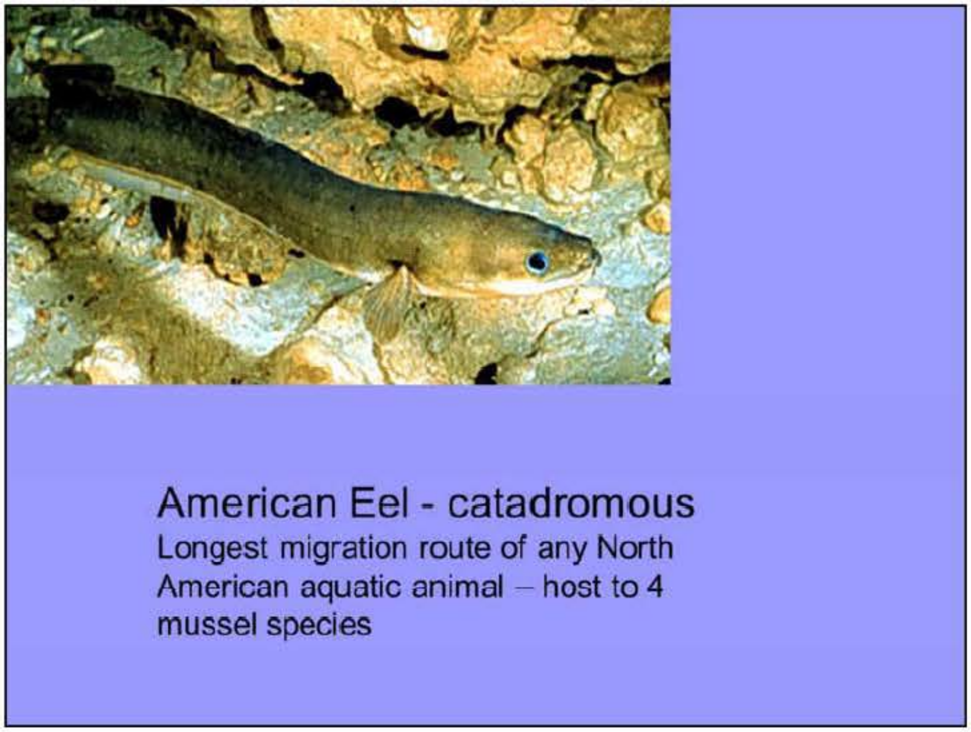
Lake sturgeon

Migrant, spawns in rapids, Lake Pepin populations historically high, likely past user of gorge rapids.
Host to hickorynut mussel.

Lake sturgeon are bottom feeders and were very numerous in the Mississippi and Lake Pepin where they grew to over 150 lbs feeding on the abundant invertebrate life on the bottom of the lake. Sturgeon also migrate to spawn in rocky rapids habitat.

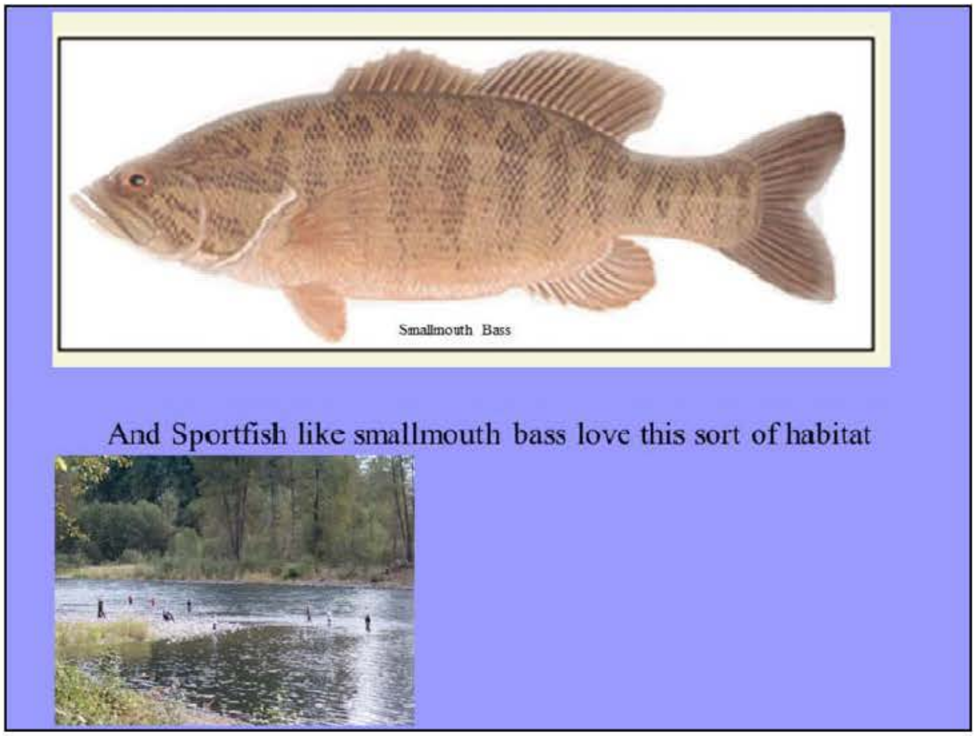


Suckers of many species once migrated to the rapids in the gorge to spawn where eagles, osprey and other predators fed on them as they piled up below the falls.

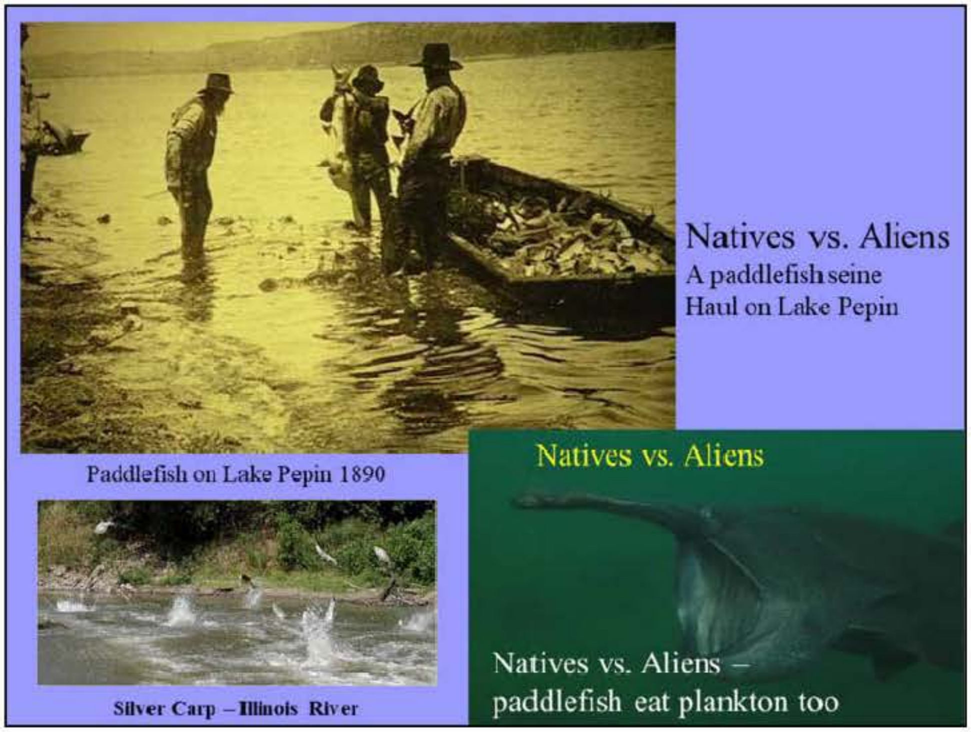


The American eel is arguably North America's most unique migrant. Adult eels migrate out of the river into the Gulf of Mexico and on into the Sargasso Sea area of the Atlantic ocean where they spawn and die. Eggs hatch and baby eels called elvers find their way back to the Mississippi River and slowly migrate upstream as they feed and grow. By the time they reach Minnesota they can have grown to be 4 feet long and 3-4 inches thick. Eels like the cover of rocks and like fish, move upstream until they reach a barrier like the Falls. On an as yet unknown cue they head back down river to repeat the life history of thousands of past generations of eels.

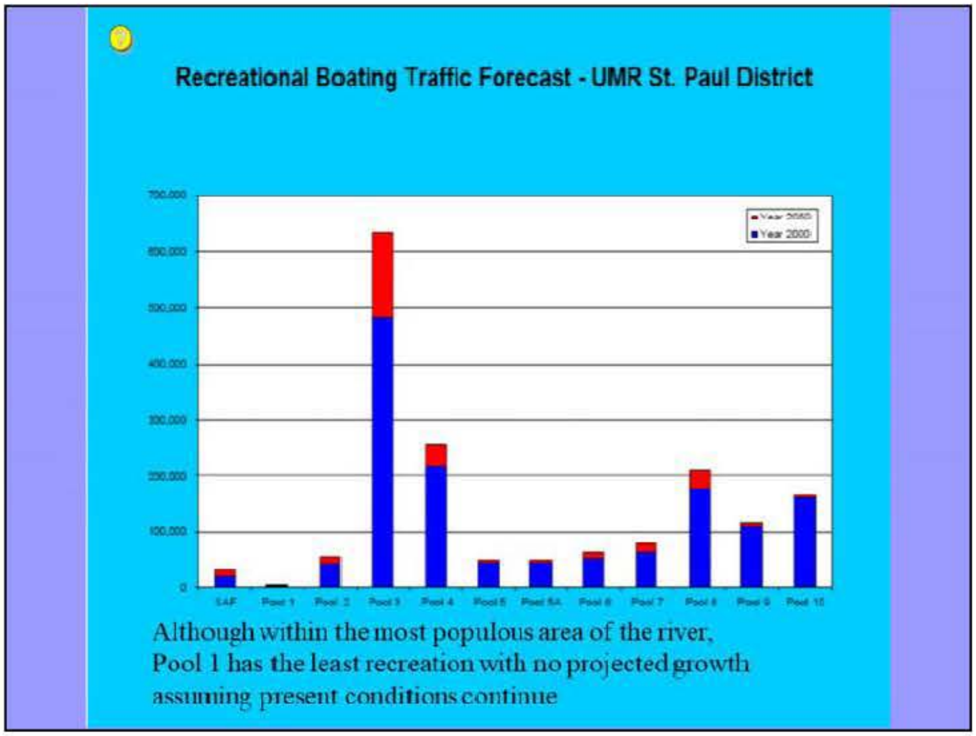
Darters are small species of fish that are rapids and riffle specialists. Many species lay their eggs inside of empty mussel shells or beneath rocks and serve as hosts to several mussel species.



Flowing water with rocky rapids are favorite habitats for smallmouth bass, a favorite quarry for many anglers., often fishing from shore.



Healthy populations of native fish species can compete with invasive fish like the silver and bighead carp.



Although Pool 1 is a relatively short navigation pool, low recreational use is likely due to poor access from shore and by boat and limited floodplain space for people when compared to other parts of the Upper Mississippi.


Our Lost Gorge-A Treasure Waiting
to be Awakened


Real Estate
Ford Bridge
Wabun Park
Lock and Dam 1
MN Veterans Home
Minnehaha Creek
St. Paul Bridge Development
Brookfield Power Plant
Hidden Falls Park
Lock and Dam 1
Corps of Engineers Owned Lands
• Fee Land (owned by Corps): 32.8 acres
• Easements: 234.48 acres
• 3 Outgrants (Corps is landowner but has authorized the use of the property by others)
Major Real Property:
▪ Lock and dam
▪ Central control station
▪ Viewing platform
▪ Storage building
▪ Service building
▪ Dam entrance building
▪ Bluff protection
▪ Cribwall

Restoration of the Mississippi River Gorge: Issues and Research Needs

Christian Lenhart

ABSTRACT

The Mississippi River Gorge has long been of central importance ecologically and economically to the Twin Cities, Minnesota region. It was unique for its high-gradient, boulder-cobble bed along the Mississippi that was valuable for fish and mussel habitat prior to alteration by locks and dams. Gorge restoration is increasingly discussed, as the river corridor is used more for recreation, commercial, and residential purposes rather than industrial uses. This study was intended to provide a synthesis of existing restoration work in the Gorge, an initial feasibility assessment of restoration actions, and to recommend next steps for restoration and research. We reviewed existing restoration activities and assessed the feasibility of restoring components of the ecosystem for ecological, historical, recreational and economic reasons, using the TELOS framework as an analytical tool. Some components of the Gorge ecosystem can be reestablished without removing the Ford Dam, which submerges part of the Gorge, including islands and historic and cultural features. However, some goals require dam removal, particularly fish and aquatic mussel passage. Future restoration is also limited by reservoir sedimentation. Some steps could be undertaken immediately to increase awareness of the Gorge's historical and ecological value and to collect further information required for restoration activities. More information is needed on the nature of sediment deposits, contaminants, and existing streambed materials before doing intensive ecological restoration. As the Ford Dam ages and maintenance costs increase while demand for parkland increases, the benefits of removal will increase.

Keywords: dam removal, Mississippi River Gorge, river restoration, Twin Cities

Restoration of the Mississippi River between St. Paul and Minneapolis, Minnesota would provide numerous economic, social, and economic benefits, yet serious constraints exist. In this case restoration would entail reestablishment of historic free-flowing, cobble/boulder bed conditions and reconstruction of some traits that have been eliminated that would be more for recreation and aesthetics than for historic ecological restoration. This 6-mi reach of the river, referred to as "the Gorge" because of its steep, canyon-like quality, is unique for the Mississippi River with its narrow confined valley, boulder-cobble bed, and associated rapids that existed prior to alteration for locks and dams (Fremling 2005) (Figures 1 and 2). Since the 1850s, the Gorge has been used primarily for industrial purposes such as milling, commercial barge traffic, and hydropower. Currently the U.S. Army Corps of Engineers (USACE) maintains the Mississippi River Gorge to support commercial navigation and aquatic recreation (River Resources Forum, 2004).

Ecological Restoration Vol. 30, No. 3, 2012
ISSN 1522-4740 E-ISSN 1543-4079

Historically, this river reach was a critical spawning area for many fish species including species that are now rare in the region, such as lake sturgeon (*Acipenser fulvescens*), because of the abundant coarse bed materials and its location downstream of the natural fish barrier posed by St. Anthony Falls (Schmidt and Talmage 2001, River Resources Forum 2004). Today, fish are blocked from entering the Gorge by Lock and Dam 1 (the Ford Dam) as well as dams located further downstream (Figure 3). The Mississippi River has a very rich diversity of aquatic species supporting at least 260 species of fishes; with 143 of these found in the Upper Mississippi above of St. Louis (Weitzell et al. 2003, Wilcox et al. 2004, MNRRA 2008). Since St. Anthony Falls was a natural barrier to aquatic species migration, as prior to lock construction, only 64% of these species are found above it (Eddy et al. 1962).

St. Anthony Falls and the Gorge have also been at the center of economic activity in the Twin Cities since the mid-1800s. Commercial milling, first for lumber and later for flour, began at St. Anthony Falls in the 1840s and quickly turned the vicinity around the falls into the industrial center of the region. Between 1880 and 1930, St. Anthony was a world leader in flour processing with major brands Pillsbury and General Mills located here (Anfinson 2003). Unfortunately, indigenous people such as the Dakota and the Ojibwe, who had revered the falls for their spiritual power, were pushed out of the area for water power development (Pennfeather 2003).

By the 1960s, industrial scale flour milling had largely disappeared from the St. Anthony Falls vicinity, leaving acres of obsolete industrial and transportation structures on both sides of the river in downtown Minneapolis (Pennfeather 2003). Beginning in the 1970s, the City of Minneapolis, the local park and recreation board, and other public and private investors began a series of redevelopment campaigns that, together, invested nearly $2 billion in the Minneapolis downtown riverfront. High-rise condominium developments and commercial building renovations popped up, miles of bicycle and walking paths were laid, and acres of land were preserved as public parks.

Meanwhile fewer boats use the uppermost locks than downstream areas with only about 20% of the boat traffic compared to downstream at Alma, Wisconsin in 2007. Most are recreational boats, though some barges use the uppermost lock and dam for gravel and scrap metal, not agricultural crops (FMR 2012). Recreational usage of the corridor and development of new commercial and residential buildings near the river in Minneapolis and St. Paul have changed public priorities for the Gorge corridor. The dense human settlement, infrastructure in and along the river, and accessibility of the river to millions of people in the Twin Cities metro area demonstrate both unique challenges and potential benefits that are typical of urban river restoration (Otto et al. 2002). In 2011 the Minneapolis Central Riverfront is once again valued for high aesthetic and recreational value and not just as a source of drinking water or hydropower for industry (City of Minneapolis 2012). Despite growing interest in a healthy river and waterfront, there is a need for more investigation into the restoration of the Mississippi River Gorge itself from an ecological, recreational, or aesthetic standpoint providing the impetus for this study.

Figure 1. The Mississippi Gorge, located downstream of St. Anthony Falls in Minneapolis and St. Paul, MN was unique for the Mississippi River, containing a high-gradient 6-mi reach of boulder-cobble-gravel streambed that was prime habitat for numerous fish and mussel species. This image is looking upstream towards the falls and upper Gorge prior to alteration for locks and dams (Reichardt, 1857, reprinted with permission of Minnesota Historical Society).

Figure 2. The current appearance of St. Anthony Falls in Minneapolis, MN. Photo Credit: Christian Lenhart.

The restoration of the Mississippi River Gorge has often been framed as an all-or-nothing proposition between dam removal and doing nothing (Rebuffoni 2003). However, there are numerous restoration options that are more feasible in the short term, (defined as <5 yrs) in addition to more complete ecological restoration via dam removal as described in Lenhart (2010). The removal of Ford Dam is not an immediate option, given the active hydropower and barge usage, and numerous, legal, logistical, and technical obstacles though it may be in the future. Removal of dams as large as the Ford Dam at 11.8 m high is rare, as the vast majority of removals have been small, <3 m high dams (Heinz Center 2002). Removal of small dams

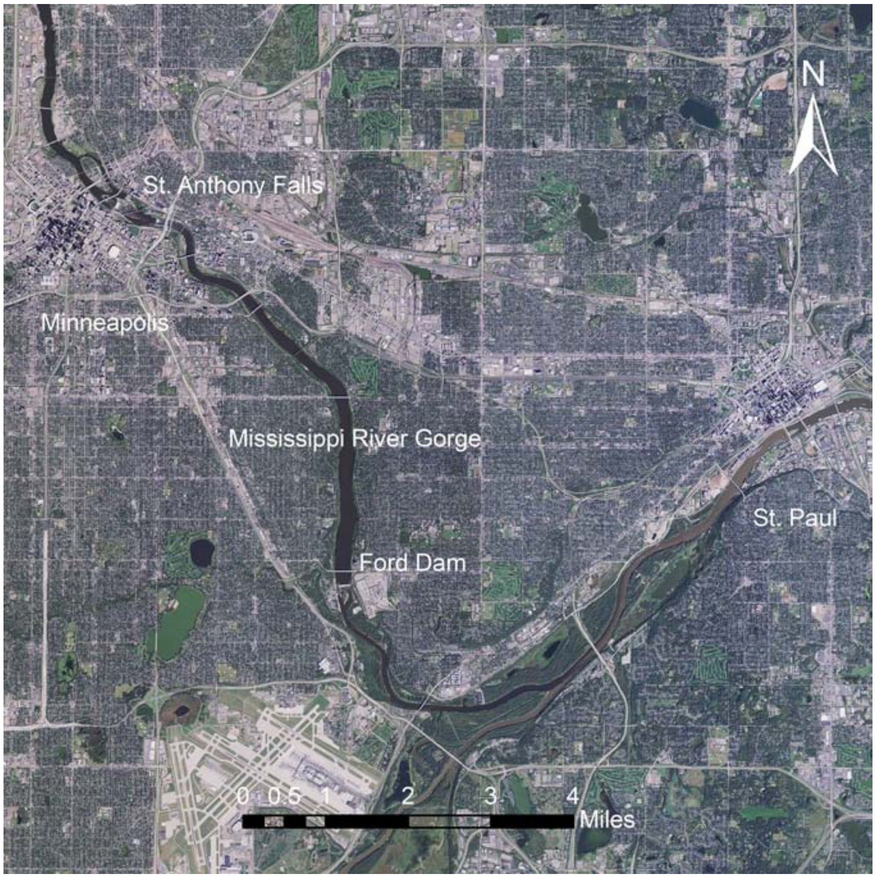


Figure 3. Location of the Mississippi River Gorge, Minnesota. The river flows from Minneapolis southward towards St. Paul and is bound by St. Anthony Falls to the north and the Ford Dam to the south.

is increasingly being done to restore ecological and geomorphic processes in rivers with thousands of small dams (less than 4 m high) removed since that time (American Rivers et al. 1999, Heinz Center 2002).

On the other hand, many ecological, historic, and recreational projects that don't require dam removal are more immediately feasible. Therefore it was recommended by the advisory committee that we examine "intermediate" restoration measures in addition to Ford Dam removal, as they are presently more agreeable to a broader stakeholder group. An initial screening of the feasibility of restoration options was proposed ranging from removal of the Ford Dam to smaller projects such as establishment of boat landings for canoeists and water level management to improve aquatic plant community coverage.

Many of the restoration options requires extensive planning among agencies and have significant constraints such as ubiquitous infrastructure and high costs, typical of large urban rivers (Riley 1998). This study was meant to be a starting point for further discussion and to promote restoration concepts that may be studied and pursued in more detail in the future.

The primary goals of this study were to provide a current synthesis of existing restoration and management work done on the Mississippi River Gorge, conduct an initial feasibility assessment of different restoration and management actions, and suggest next steps and further research needs. More specifically, this study was intended to: 1) summarize existing work and identify gaps and opportunities in restoration and management of the Gorge; 2) provide an initial feasibility assessment of restoration and management actions within the Gorge and identify further study needs; and 3) recommend potential actions that can be undertaken immediately (0–5 yr) and in the longer term (>5 yr) for river restoration as well as further research needs to conduct more intensive restoration actions.

Study Area

We focused on the river reach between St. Anthony Falls and St. Paul (Figure 3), (the area contained within Pool One of the USACE Lock and Dam System, the uppermost in the lock and dam system built for commercial shipping). Adjacent reaches were studied in less detail to address connectivity of physical and ecological processes. For example, the St. Croix River, a large tributary to the Mississippi found just downstream of St. Paul contains a wealth of mussel diversity that is currently blocked from entering the Gorge (via fish which carry the mussel larvae) by the next dam downstream at Hastings, Minnesota (Sietman 2003).

Study Approach

We focused on examining existing information relevant to restoration of the Gorge and management plans of local, state, and federal governments and non-profit organizations were reviewed to characterize the work currently being done and identify gaps and opportunities in restoration and management of the Gorge (Table 1).

We also examined existing data sources on geomorphology, sediment characteristics, and water quality. Historic geomorphology data was available from the Mississippi River Commission maps of 1895, containing detailed cross sectional, bed material, and water depth data and the location of islands. More recent data on the sediment characteristics of the bed deposits behind Ford Dam were obtained from the Minnesota Department of Natural Resources (DNR), who analyzed the data collected by the USACE.

An initial feasibility screening of restoration and management actions within the Gorge was done to target promising strategies for more detailed analysis and future implementation. To more specifically define the feasibility of river restoration, the 5 categories outlined in the TELOS framework (*T*echnology, *E*conomic, *L*egal, *O*perational and *S*chedule) were used with an ecological category added (Bentley and Whitten 2007). TELOS provides a useful analytical framework for initial screening of ecological restoration feasibility because the categories within it help to identify practical issues that are often overlooked in ecological or economic assessment alone. The rankings assigned in TELOS were determined subjectively after reviewing existing material and talking to people knowledgeable about the project, including the advisory committee. For example, the physical constraints associated with river restoration involving hydrology, geomorphology, and channel alterations were examined under the *Technology* category. *Economic* issues were considered including commercial barge and hydropower uses, river recreation, tourism, and aesthetics. *Legal* issues of regulatory and management authority, including maintenance of the 9-ft barge channel were examined in more detail. *Operational* issues or practical problems related to river restoration while operating a lock and dam system were investigated, such as the logistics of water level drawdown and its impact on barge traffic. *Schedule* issues, including such issues as the timescale for restoration and management actions, the seasonality of water level variation, and the duration of hydropower licenses were considered. *Ecological* feasibility was assessed by identification of potential negative impacts, since it is assumed that the positive impacts of restoration projects are clearly identified. Invasive species expansion and release of pollutants from sediment mobilization after dam

Table 1. Key management plans reviewed in the Twin Cities reach of the Mississippi River, Minnesota. Listed plans represent those most relevant to restoration activities in the Gorge.

Plan type or name	Agency responsible
Federal	
Environmental Pool Plans	Fish and Wildlife Work Group—US Army Corps of Engineers and River Resources Forum
Ford Dam Hydropower License	Federal Energy Regulatory Commission (FERC)
Mississippi National River (MNRRA) Recreation Area	National Park Service
State	
Minnesota River Corridor Critical Area Report	Minnesota DNR
Minnesota Pollution Control Agency	Total maximum daily load studies (TMDL) studies for turbidity and bacteria
Local	
Above the Falls Master Plan	City of Minneapolis and Hennepin County
Saint Paul Comp. Plan 2020—Water Resources Management Plan	Saint Paul City Council
Watershed Management Plan	(MWMO) Mississippi Watershed Management Organization
Non-Governmental Organizations (NGOs)	
Mississippi River Gorge Ecological Inventory and Restoration Management Plan	Great River Greening (GRG)
Annual Report 2007 and Website	Friends of the Mississippi River

Table 2. Strategies reviewed in the identification of issues and research needs for the restoration of the Mississippi River Gorge, Minnesota.

Category	Restoration action	Specific case
Geomorphic and Sediment Transport Processes	Restoring boulder cobble bed for fish habitat; reestablishing sediment transport with free-flowing river; Restoring in-channel features: islands, sandbars, and mudflats	Dam removal, water level drawdown at Ford Dam, Reconstructing islands that were dredged or submerged
Hydrology and water quality processes	Restoration of flow regime (river depth, velocity, discharge, timing)	Water quality improvement- sediment and nutrients
Ecological processes (vegetation, fish and wildlife)	Reestablishment of plant communities altered by lock and dam system; fish and mussel passage at dams	Mussel restoration, fish passage, restoration of submerged aquatic and emergent vegetation
Socio-Economic factors	Promote social and economic drivers favoring restoration	Improved access to river; better valuation of ecological services
Aesthetic factors	Waterfall restoration	Aesthetic enhancement of St. Anthony Falls and other Gorge features
Recreation factors	Canoe access sites; whitewater rapid restoration; improved fishing	Reestablishment of rapids for whitewater boating

removal are examples of issues that impact project feasibility. A range of restoration options was characterized in this way (Table 2).

In conjunction with the feasibility study, an advisory committee consisting of government, university, and non-profit organizations offered feedback on the study and recommendations for follow-up actions to the preliminary study. One of the committee's main recommendations was to examine intermediate restoration actions short of dam removal.

Findings and Discussion

Synthesis of Existing Restoration and Management Work: Gaps and Opportunities

Many local, state, federal, and non-governmental entities are involved with management of the Gorge (Table 1). Most current restoration and management work near the Gorge has focused on tributary watersheds and upland vegetation management by NGOs, the National Park Service, and local government units (City of Minneapolis Parks and Recreation Board and several local watershed districts). The focus on uplands is because competing uses for hydropower and barge traffic have precluded in-stream restoration actions. However much in-stream restoration work has been done in other parts of the upper Mississippi River (O'Donnell and Galat 2007), including reaches just downstream of the Twin Cities.

Within the Gorge itself, numerous management efforts have been made to improve water quality and clean up excess sediment, nutrients, and pollutants led by the MPCA and local watershed management organizations. Currently total maximum daily load (TMDL) studies are being undertaken to document sources and loads of pollutants, including fecal coliform bacteria and turbidity (MPCA 2009). Strategies for reducing pollutants below TMDL load allocation would complement river restoration efforts by making conditions more suitable for aquatic flora and fauna (MPCA 2012). While the Mississippi River in the Twin Cities supported almost no mussels in the 1970s prior to the Clean Water Act, a recent survey of Pool Two found 18 mussel species including the Higgins' eye pearly mussel (*Lampsilis higginsii*), a federally endangered species, and the elktoe (*Alasmidonta marginata*), a state threatened mussel (Davis 2005). Building on this recovery of mussel populations, the Minnesota DNR, U.S. Fish and Wildlife Service and USACE have actively re-established additional native mussel species to a reach just downstream of the Gorge in Pool Two. Despite the positive success of mussel reestablishment, little has been done to restore hydrologic and geomorphic processes altered by the dams in the Gorge that would increase the sustainability of efforts to restore aquatic biota extirpated from this river reach.

In addition to the ecological restoration and management efforts, a variety of public agencies have undertaken planning and education efforts that have, together, created an impetus for restoration of recreational, historic and aesthetically-significant features of the Gorge. The National Park Service now conducts tours of natural and historic features along the river to educate the public. At the upstream end of the Gorge, near St. Anthony Falls, the Minneapolis Park and Recreation Board has developed recreation space on floodplain parks to serve the public. Neighborhood-driven volunteer efforts have concentrated on plant community restoration on the uplands above the river, working to diminish invasive buckthorn infestations and reestablish more native oak forest and oak-savanna. Stream restoration projects have been done on Minnehaha Creek, a large tributary west of the Gorge as well.

The major gap in restoration work is in the river itself. There is increasing opportunity for restoration work on the upstream end of the Gorge at St. Anthony Falls and immediately upstream of the falls in Minneapolis. Currently the City of Minneapolis Park and Recreation Board and its partners are planning that type of work.

Feasibility Assessment Using TELOS Analysis

Overall, the evaluation indicated that some restoration strategies would be feasible, particularly from technical, ecological, and operational standpoints. However, economic and legal issues are the primary limitation for restoration due to the high cost of large river restoration and complexity of regulation and stakeholder interests. For example, removal of the Ford Dam may be technically feasible, but the Federal Energy Regulatory Commission (FERC) hydropower license, which extends for another 2 decades, and the general need for clean energy sources provide incentives for maintaining the Ford Dam. There are other economic, social, and legal barriers as well. From a legal standpoint, hydropower production and the maintenance of the 9-ft barge channel limit the short-term (< 5 yrs) feasibility of ecological restoration. In the short term, permanent drawdown (or removal) is not practical from a political and legal standpoint as decommissioning the barge channel would require alteration to the USACE management plan for Pool One and approval of Congress. Although extensive river restoration is unlikely at present, when the next re-licensing of the Ford Dam occurs around 2030 an opportunity will arise for ecological improvement.

Economically, the industrial benefits of commercial barge traffic and hydropower production are well defined, yet many ecological services provided by the river corridor are poorly understood. The quantification of ecological benefits is a fairly new science. Therefore, ecological, recreational and aesthetic services tend to be undervalued because economic methods for measuring them are not

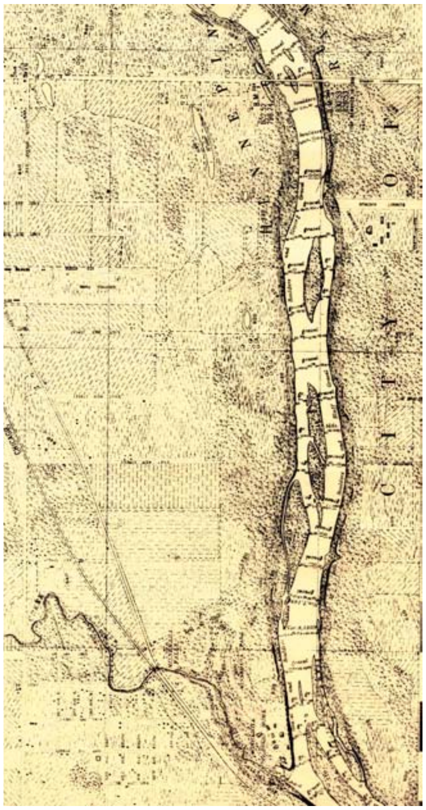


Figure 4. Mississippi River Gorge, Minnesota, in 1895, prior to most of the lock and dam alterations. Numerous islands and narrower side channels existed in the Mississippi River, creating a variety of water depths, substratum, and aquatic plant communities. Reestablishment of islands in the Gorge was one options examined in this study (MRC 1895).

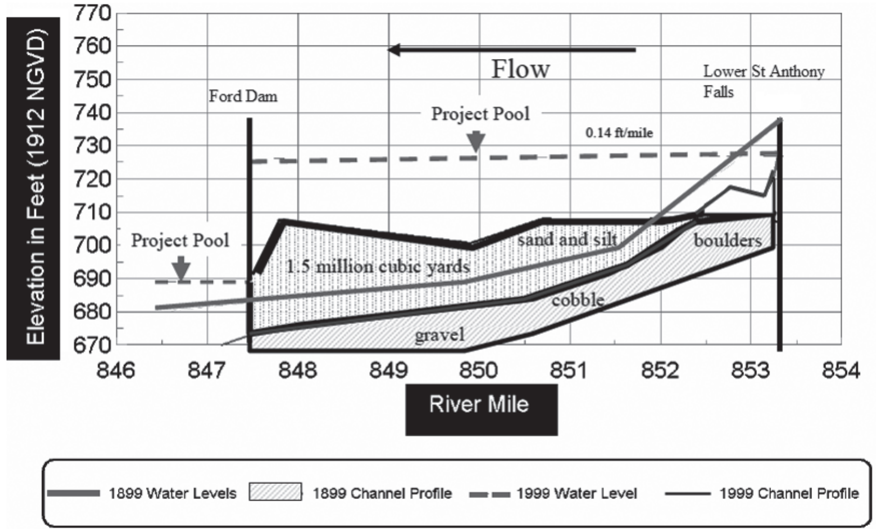


Figure 5. Sediment deposit in Pool 1 of the Mississippi River, Minnesota, behind Ford Dam. The top hatched area shows the sediment deposit on top of the historic 1895 river bed elevation. The dashed line shows the current Pool 1 elevation, while the solid black line below it shows the approximate 1899 water level, and the solid black line below the water level shows the 1999 bed elevation. The solid gray line shows the approximate 1899 water level, while the lower solid black line shows the approximate 1899 bed elevation.. Sedimentation behind the Ford Dam would be one of the major challenges to more intensive river restoration efforts by dam removal (Scot Johnson, Minnesota Department of Natural Resources, personal communication).

well developed (Smith et al. 2006). Consequently, there is a skewed view of true costs and benefits.

From an operational and schedule perspective dam removal would eliminate barge shipping above the Ford Dam. However barge shipping historically stopped at St. Paul until about 1965 when Lock and Dam #1 was completed, due to the steep rocky rapids in the Gorge that prevented large barges from entering (Anfinson 2003). On the other hand, if seasonal drawdown were done rather than dam removal, only temporary boat restrictions would occur (Vaselaar 1997).

Feasibility of Restoring Hydrology and Geomorphology Processes

Prior to alteration for the lock and dam system, there were 10 km of coarse streambed, with scattered islands most of which are now submerged by Pool 1 (Figure 4) and buried under sediment, primarily sand and silt (Figure 5). Re-exposing some of the streambed could be accomplished by removal of Ford Dam or possibly by seasonal releases of water. Hydrologic variability could be increased through seasonal water level drawdown to recreate the high and low flow levels typical of a natural river that would benefit riparian plant communities (Junk et al. 1989).

Islands used to be prevalent in this stretch of river but are hard to restore short of dam removal, since Pool 1 is 11 m deep. Island reconstruction would be more feasible in the upper Gorge near Lower St. Anthony Falls because of the shallower depth. The USACE has installed several island restoration projects in the Mississippi River between Minnesota and Wisconsin in Pools 4–8 (Soballe and Gaugush 1994), demonstrating the feasibility of such projects. The geomorphic processes of sediment deposition and mobilization are 2 of the largest issues related to dam impacts and dam removal. The dams capture large volumes of sediment (Figure 5) which may be flushed downstream upon dam removal and high flows. Yet, strategies exist for managing this including staged water level drawdown over a period of years to temporarily stabilize reservoir sediments and minimize downstream impacts.

Feasibility of Restoring Ecological Processes

There is potentially great benefit to fish and mussel restoration because of the great habitat value of the Gorge with its boulder-cobble bed (Davis 2005). The vast majority of fish and mussels are now blocked from reaching their former spawning/nesting grounds. Furthermore, although coarse bed materials are still found at the upper end of the Gorge, most of it has been buried by finer sediments (Figure 5). It may be possible to increase fish and mussel passage during spring high flows by opening up the lock gates of Ford Dam, except that the current lock gates may not withstand the high velocities exposed at high flows (Wilcox et al. 2004). Construction of a fish ladder would not be very feasible, costing tens of millions of dollars due to the height of the dam and narrowness of the Gorge, restricting the layout of the ladder.

Even without dam removal or fish passage improvements, it is possible to improve habitat conditions within Pool 1 for species like smallmouth bass (*Micropterus dolomieu*) and walleye (*Sander vitreus)* by removing sediment to expose spawning grounds and/or replacing boulders that had been dredged from main channel and placed on the sides of the upper Gorge. Diversity of in-stream vegetative communities could also be enhanced by water level variation in Pool 1 to establish more aquatic and littoral vegetation zones. Currently Pool 1 contains only open water and limited floodplain forest communities (Theiling 1995) although a great variety of plant communities exist in the river valley downstream of St. Paul (Peck and Smart 1986).

Range expansion of invasive fish species is a major concern associated with dam removal or fish passage projects, particularly of the silver carp (*Hypophthalmichthys molitrix)* and related species that are now found in the Mississippi River near the Twin Cities. However, since the Ford and St. Anthony Dams act as only partial barriers to fish passage, this is not a major obstacle to gorge restoration. Currently the upstream Coon Rapids Dam serves as the primary barrier to upstream migration in the Mississippi River (River Resources Forum 2004). However water samples suggest that Asian carp are now present above Coon Rapids also (Gihring 2011).

Feasibility of Restoring Historic and Aesthetic Features

Some historic features of the Gorge have been re-discovered and made into parkland including the Mill Ruin Park, with structures dating from the 1800s near St. Anthony Falls. Other opportunities exist including installation of educational signage on the defunct Winchell Dam, Native American sites and early European-American settlements. The restoration of streamflow in side-waterfalls (which are described in Arey 1998) has been considered at Bridal Veil Falls but the highly variable nature of urban runoff from the impervious area means that the few remaining waterfalls only flow after storm events. From a corridor-wide planning perspective, management to maintain a natural aesthetic along the Gorge is an important goal in the National Park Service's National Recreation Area (Mullan 2009).

Potential Next Steps and Future Research Needs

In summary, removing Ford Dam as a migration barrier to numerous fish and mussel species makes its removal ecologically valuable. However, numerous issues challenge its removal. The reservoir (Pool 1), which submerges much of the Gorge, does contain a large sediment deposit (Figure 5) that could pose a threat to downstream aquatic life if managed improperly. Strategies for stabilizing and managing sediment release during drawdown and removal have been developed in recent years that could mitigate any negative impacts.

In terms of partial activities, many restoration actions are technically possible at the present time although numerous barriers exist in large, urban rivers such as the Gorge. A myriad of socio-economic, regulatory and scientific challenges make large river restoration generally more challenging and this is true for the Gorge. The large spatial scale of major river basins, complex ownership, and regulatory schemes make water quality improvements challenging (McGuiness 2000). Legal, political and economic issues are more complex over large river basins, particularly in urban areas (Riley 1998). From a physical perspective, small rivers are easier to manipulate and re-shape through reestablishment of sinuosity, streambank stabilization or grade-control structures. In addition there is a lack of experience for this type of project as most practical stream restoration experience has come from small streams, not large rivers because of inherent difficulties in scale that arise (Palmer et al. 2007).

On the other hand, much can be done to restore historic, aesthetic, cultural and recreational features of the Gorge short of dam removal. A list of short-term actions that could be undertaken in the next five years was developed as a result of this study (Table 3). But in order to achieve long-lasting restoration of the Gorge ecosystem, connectivity would have to be established for aquatic biota. Also, hydrologic and geomorphic regimes would have to be re-established by removal of Ford Dam. Removal of such a large dam would require public demand and favorable economics.

Large urban rivers support multiple recreational, aesthetic and economic functions (McGuinness 2000), calling for an increased management focus on recreation and other human uses. Urban parklands have very high user rates, and great value is placed on recreational space and aesthetic values (Kenney et al. 2012), so the potential benefits of restoration are great compared to streams in more remote settings. Even partial restoration of Gorge features, such as islands or enhanced aesthetics at St. Anthony Falls could have much greater value than is currently recognized, because the benefits of ecological restoration have not been adequately calculated (Smith et al. 2006). As an illustration of this point, Fort Snelling State Park, the most visited state park in Minnesota, is located on the Mississippi River in St. Paul. This suggests great potential usage of restored parkland in the Gorge (MN Trails 2008).

To further advance Gorge restoration there needs to be increased public awareness of the value of the Gorge, ecologically, recreationally and economically. Currently several such education efforts are being undertaken

Table 3: Recommended actions and further research needs for restoration of Mississippi River Gorge, Minnesota.

Category	Recommended Actions	Further Studies Needed
Physical processes: geomorphic and hydrologic restoration	Collect data on characteristics and contaminants of Pool 1 sediment deposit; need better understanding of area exposed by drawdown or removal of Ford Dam	Study of stage-discharge relations in drawdown scenarios; sediment transport with dam
Ecological processes: fish, wildlife and vegetation	Examine restoration of plant communities through water level drawdown; potential fish and mussel habitat projects in the Gorge	Modeling of water level management and dam removal scenarios
Economic processes: valuing river services and functions	Document economic value of ecological services and passive recreational uses in Gorge such as running, hiking, canoeing	Study to quantify value of ecological services.
Large river restoration issues	Assess feasibility of restoration actions in more detail with consideration to large river issues	Determine ways to balance multiple uses in large urban area

by universities, government agencies and NGOs. A more detailed technical feasibility study would be required to build on this preliminary assessment and identify future Gorge restoration and management actions. Issues that should be examined in more detail include parkland expansion by exposing submerged land via water level management or dam removal.

Several economic and legal factors could drive ecological restoration of the Gorge forward. As the Ford Dam ages and becomes increasingly expensive to maintain, it will become less attractive to private hydropower interests. Currently the USACE maintains the lock and dams, providing great cost-savings to the Canadian hydropower company operating the dam. If the locks and dams were closed to barge traffic, than maintenance costs would fall on the dam company, greatly reducing its benefit-to-cost ratio. At this point, dam removal would become much more feasible. The FERC relicensing of Ford Dam will come up in 2034 presenting the opportunity to address the issue then, if it does not arise earlier.

Specific steps were identified to continue the restoration planning process. Actions include holding a Mississippi River Restoration symposium to solicit comments and develop a consensus on research needs, meeting with river stakeholders about restoration, developing an agreement on the feasibility and priority of next steps, and expanding information available on the internet from this study.

At this stage restoration is primarily a future scenario, although there are immediate steps that are feasible at least from a technical standpoint to facilitate the re-establishment of physical, geomorphic, and sediment transport processes. These include a number of steps that have low risk or require no permanent alteration such as conducting a test drawdown of Lower St. Anthony Falls and Ford Dam to identify bed material traits and dredging additional sediment from streambed of Pool 1 to expose coarse bed material. At this point much more information is needed before moving ahead with intensive restoration. Data collection on the characteristics and contaminants of Pool 1 sediment deposit is needed as is modeling of water level management and/or dam removal scenarios. The identification of potential locations to reestablish islands removed by dredging would be helpful as well.

Some restoration of ecological processes may be accomplished in the short-term including continued freshwater mussel reestablishment activities and investigating issues with improving fish and mussel passage around the Ford and Hastings Dams. The restoration of plant communities through water level drawdown should be studied in more detail to map potential restoration areas. There is also potential for the reestablishment of side waterfalls that occurred along the Gorge walls, such as Bridal Veil Falls which are not impacted by the Ford Dam.

Additionally, many educational, social and recreational actions could be undertaken including establishment of more educational signage on natural and human history of the Gorge. Plans to identify locations for parkland if Pool 1 were drained down and canoe stopover points for use with National Park Service-led youth canoe trips and others could be designed today.

One of the main factors influencing the decision to move forward with different restoration strategies is the balance of costs and benefits. Currently there are well-established cost and benefit values for traditional commercial uses of the river such as shipping and hydropower. There is a strong need to conduct research to better document and quantify the economic value of ecological, recreational and aesthetic factors to river users, residents and tourists. If these factors were more accurately accounted for the favorability of many ecological restoration and management actions would increase.

Conclusion

The Mississippi River Gorge has long been one of the major ecological, economic and aesthetic resources of the upper Mississippi River valley region. Removal of the Ford Dam would reestablish the hydrologic and sediment transport regime and allow for more complete ecological restoration including passage of fish and aquatic mussels and reestablishment of aquatic plant communities. However numerous legal, economic, logistic and sediment concerns exist making this option impractical at the present time. Meanwhile, numerous aesthetic, recreational, and historic projects could be undertaken. Some are already being pursued around St. Anthony Falls and along the river upstream of the Gorge. Over the longer time period of the next 10 to 20 years, restoration of the Gorge may become more favorable in terms of the cost-benefit balance given the increasing value of urban parkland and the revitalization of the riverfront in both St. Paul and Minneapolis that is now occurring. Several more in-depth technical studies would be needed before that restoration could occur.

Acknowledgements

This research was supported with a grant from the McKnight Foundation from 2009—2010. Advisory committee members included Mike Davis, Minnesota DNR; Deborah Karasov, Great River Greening; Joe Magner, Minnesota Pollution Control Agency and University of Minnesota; Paul Labovitz, National Park Service, Pat Nunnally, University of Minnesota—River Life Program and Doug Snyder, Mississippi Watershed Management Organization. John Nieber, a University of Minnesota professor in the Department of Bioproducts and Biosystems Engineering provided invaluable input to the project and the original proposal. Lucius Jonett, formerly a graduate student at the University of Minnesota conducted a literature review and collected information on existing restoration and management work. Mike Davis, Deborah Karasov, Paul Labovitz and Pat Nunnally all provided helpful comments on the manuscript.

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Common name	Scientific name	Group	Federal status	State status	Habitat needs
Black Sandshell	*Ligumia recta*	Mussel	None	Special concern	Large river rapids
Butterfly	*Ellipsaria lineolata*	Mussel	None	Threatened	Large river rapids
Ebonyshell	*Reginaia ebenus*	Mussel	None	Endangered	Large river rapids
Elephant-ear	*Elliptio crassidens*	Mussel	None	Endangered	Large river rapids
Elktoe*	*Alasmidonta marginata*	Mussel	None	Threatened	Large river rapids
Fawnsfoot	*Truncilla donaciformis*	Mussel	None	Threatened	Large river rapids
Fluted-shell*	*Lasmigona costata*	Mussel	None	Threatened	Large river rapids
Higgins Eye	*Lampsilis higginsii*	Mussel	Endangered	Endangered	Large river rapids
Monkeyface	*Theliderma metanevra*	Mussel	None	Threatened	Large river rapids
Mucket	*Actinonaias ligamentina*	Mussel	None	Threatened	Large river rapids
Pistolgrip	*Tritogonia verrucosa*	Mussel	None	Endangered	Large river rapids
Purple Wartyback	*Cyclonaias tuberculata*	Mussel	None	Endangered	Large river rapids
Rock Pocketbook	*Arcidens confragosus*	Mussel	None	Endangered	Large river rapids
Round Pigtoe	*Pleurobema sintoxia*	Mussel	None	Special concern	Large river rapids
Salamander Mussel*	*Simpsonaias ambigua*	Mussel	None	Endangered	Large river rapids
Sheepnose	*Plethobasus cyphyus*	Mussel	Endangered	Endangered	Large river rapids

Snuffbox*	*Epioblasma triquetra*	Mussel	Endangered	Endangered	Large river rapids
Spectaclecase*	*Cumberlandia monodonta*	Mussel	Endangered	Endangered	Large river rapids
Spike	*Eurynia dilatata*	Mussel	None	Threatened	Large river rapids
Wartyback	*Quadrula nodulata*	Mussel	None	Threatened	Large river rapids
Washboard	*Megalonaias nervosa*	Mussel	None	Endangered	Large river rapids
Winged Mapleleaf	*Quadrula fragosa*	Mussel	Endangered	Endangered	Large river rapids
Black Buffalo	*Ictiobus niger*	Mussel	None	Threatened	Shallow, fast moving river habitat
Blue Sucker*	*Cycleptus elongatus*	Mussel	None	Special concern	Large river rapids
Crystal Darter	*Crystallaria asprella*	Fish	None	Endangered	Sandy rapids
Lake Sturgeon*	*Acipenser fulvescens*	Fish	None	Special concern	Large river rapids
Mississippi Silvery Minnow*	*Hybognathus nuchalis*	Fish	None	Special concern	Large river rapids
Paddlefish*	*Polyodon spathula*	Fish	None	Threatened	Large river rapids
Pallid Shiner*	*Hybopsis amnis*	Fish	None	Endangered	Large river rapids
Skipjack Herring*	*Alosa chrysochloris*	Fish	None	Endangered	Large river rapids
Suckermouth Minnow*	*Phenacobius mirabilis*	Fish	None	Special concern	Large river rapids
Blanchard's Cricket Frog	*Acris blanchardi*	Amphibian	None	Endangered	Shallow river and floodplain forest habitat
Mudpuppy*	*Necturus maculosus*	Amphibian	None	Special concern	Rocky river habitat
Blanding's Turtle	*Emydoidea blandingii*	Reptile	None	Threatened	River and floodplain forest habitat
Smooth Softshell	*Apalone mutica*	Reptile	None	Special concern	Sandy river habitat
Wood Turtle	*Glyptemys insculpta*	Reptile	None	Threatened	Shallow, fast moving river habitat
Cerulean Warbler	*Setophaga cerulea*	Bird	None	Special concern	Floodplain forest habitat

Common Gallinule	*Gallinula galeata*	Bird	None	Special concern	River habitat
Louisiana Waterthrush	*Parkesia motacilla*	Bird	None	Special concern	Floodplain forest habitat
Purple Martin	*Progne subis*	Bird	None	Special concern	Floodplain forest habitat
Red-shouldered Hawk	*Buteo lineatus*	Bird	None	Special concern	Floodplain forest habitat
Big Brown Bat	*Eptesicus fuscus*	Mammal	None	Special concern	Floodplain forest for summer foraging
Little Brown Myotis	*Myotis lucifugus*	Mammal	None	Special concern	Floodplain forest habitat for summer foraging
Northern Long-eared Bat	*Myotis septentrionalis*	Mammal	Threatened	Special concern	Floodplain forest habitat for summer foraging
Discoid Beggarticks	*Bidens discoidea*	Vascular plant	None	Special concern	River slough habitat
Gray's Sedge	*Carex grayi*	Vascular plant	None	Special concern	Floodplain forest habitat
Green Dragon	*Arisaema dracontium*	Vascular plant	None	Special concern	Floodplain forest habitat
Muskingum Sedge	*Carex muskingumensis*	Vascular plant	None	Special concern	Floodplain forest habitat
Ovate-leaved Skullcap	*Scutellaria ovata var. versicolor*	Vascular plant	None	Threatened	Floodplain forest habitat
Sessile-flowered Yellow Cress	*Rorippa sessiliflora*	Vascular plant	None	Special concern	River flood pulses
Snow Trillium	*Trillium nivale*	Vascular plant	None	Special concern	Floodplain forest habitat
Swamp White Oak	*Quercus bicolor*	Vascular plant	None	Special concern	Floodplain forest habitat
Sand-loving Laccaria	*Laccaria trullisata*	Fungus	None	Special concern	Beach habitat
A Caddisfly	*Oecetis ditissa*	Insect	None	Threatened	Shallow, fast moving river habitat
A Caddisfly	*Protoptila erotica*	Insect	None	Special concern	Shallow, fast moving river habitat

*Species whose recovery would be greatly enhanced.

List was initially downloaded from Minnesota Department of Natural Resources' Rare Species Database using the following search terms: Miss R & L Pepin; Mississippi River; Habitats: Large Rivers; Medium Rivers and Streams; Floodplain Forest; River Shore. Once downloaded, species were reviewed for dependence on rapids habitat. List was then shared with Minnesota DNR biologists for feedback.

From: Davis, Mike J (DNR)
To: Olivia Dorothy
Subject: RE: Question about removal of LSAF & LD1
Date: Thursday, October 20, 2022 9:45:41 AM
Attachments: image002.png
image003.png
image004.png
image005.png

Hi Olivia,

If the Disposition Study results in the removal of the dams at L&D 1 and LSAF it could result in restoring the physical habitat of the gorge while allowing fish that serve as hosts for many species of state and federally Threatened and Endangered mussels to bring them up river and into the type of habitat that they need to survive and begin reproducing. This could increase the likelihood of recovering and delisting these species. This unique riverine habitat could once again support the federally Endangered Winged Mapleleaf, Spectaclecase, Snuffbox, Higgins' Eye and Sheepnose mussels that once lived in this part of the Mississippi River.

Mike

Mike Davis
NR Program Consultant / Division of Ecological and Water Resources
Minnesota Department of Natural Resources
Center for Aquatic Mollusk Programs (CAMP)
2109 N. Lakeshore Dr.
Lake City, MN 55041
[redacted]
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From: Olivia Dorothy [redacted]
Sent: Thursday, October 20, 2022 9:21 AM
To: Davis, Mike J (DNR) [redacted]
Subject: Question about removal of LSAF & LD1

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Mike, can you please explain to me how removing Lower St Anthony Falls Dam and Lock and Dam 1 might help threatened and endangered mussel populations? Thanks for your help!

Olivia Dorothy, CFM
Director, River Restoration
Pronouns: she|her|hers *why do pronouns matter?*

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