

Comments on the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)

Submitted by

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Great Rivers Environmental Law Center
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November 25, 2013

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The National Wildlife Federation, Great Rivers Environmental Law Center, Kentucky Waterways Alliance, Missouri Coalition for the Environment, Missouri Parks Association, and Sierra Club (collectively, the Conservation Organizations) appreciate the opportunity to submit these comments on the Draft Environmental Impact Statement (DEIS) for the St. Johns Bayou and New Madrid Floodway Project. The Conservation Organizations also ask the Corps to treat a resubmitted all the comments previously submitted by the National Wildlife Federation and/or the Environmental Defense Fund on previous environmental impact statements for the Project as though fully set forth herein.

The Conservation Organizations strongly oppose the St. Johns Bayou New Madrid Floodway Project (the Project) and urge the U.S. Army Corps of Engineers (Corps) to abandon the Project and select the no action alternative. Should the Corps choose to pursue the Project despite its devastating environmental impacts, the Conservation Organizations call on the Environmental Protection Agency to veto the project under Section 404(c) of the Clean Water Act, and call on the Department of the Interior to refer the project to the Council on Environmental Quality pursuant to 42 U.S.C. § 4344.

The National Wildlife Federation (NWF) is the nation's largest conservation education and advocacy organization. NWF has more than four million members and supporters and conservation affiliate organizations in forty-eight states and territories. NWF has a long history of working to protect the nation's coasts, rivers, wetlands and floodplains, and the fish and wildlife that depend on those vital resources. NWF also has a long history of advocating for the protection and restoration of the Mississippi River and on working to ensure that federal water projects are environmentally and economically sound.

Great Rivers Environmental Law Center is a nonprofit organization dedicated to providing free and reduced-fee public interest legal services to individuals and organizations working to protect and preserve Missouri's environment.

Kentucky Waterways Alliance is a statewide nonprofit organization dedicated to protecting and restoring the waters of the Commonwealth. Kentucky Waterways Alliance represents over 900 members and affiliate organizations united to insure high quality water resources in Kentucky for diverse recreational activities such as swimming, boating, and fishing as well as reliable drinking water supplies and biological habitat.

Missouri Coalition for the Environment is Missouri's independent, citizens environmental organization for clean water, clean air, clean energy, and a healthy environment. The Missouri Coalition for the Environment works to protect and restore the environment through education, public engagement, and legal action.

Missouri Parks Association is a non-profit citizens organization—independent and non-partisan—of more than 3,000 members statewide dedicated to the protection, enhancement, and interpretation of Missouri state parks and historic sites. MPA has long advocated for restoration of hydrologic and ecosystem function in a scientifically sound and sustainable manner along the great rivers, where Missouri has twenty state parks including Big Oak Tree.

Sierra Club is the nation's oldest, grassroots based environmental organization. Founded in 1892 the Sierra Club has over 603,000 members united to explore, enjoy and protect the wild places of the Earth; to practice and promote the responsible use of the Earth's ecosystems and resources; and to educate and enlist humanity to protect and restore the quality of the natural and human environment.

I. Overview of Comments

The Project violates federal law and policy and is fundamentally at odds with modern science. The Project will cause devastating harm to the environment and to fish and wildlife that cannot be mitigated. As aptly stated by FWS, the “project-related wetlands losses are at odds with the federal conservation policy goals and sustainable water resources development.”¹ The Corps’ own Assistant Director of Civil Works has aptly described the project as an “economic dud” with “huge environmental consequences.”²

The project’s defining component – a new levee to close the last connection between the Mississippi River and its natural backwater habitat in the State of Missouri – will end backwater flooding on 75,000 acres and eliminate the most important backwater spawning and rearing habitat in the Middle Mississippi River. The U.S. Fish and Wildlife Service (FWS) has repeatedly stated that this will “cause substantial, irretrievable losses of nationally significant fish and wildlife resources, and greatly diminish rare and unique habitats found in southeast Missouri.”³ Many experts have concluded that the adverse impacts of the Project are so significant that they cannot be mitigated.

The Draft EIS provides a fundamentally flawed analysis of the impacts of the Project and fails to comply with the requirements of the National Environmental Policy Act (NEPA). The DEIS relies on outdated model and data and lacks scientific integrity; fails to demonstrate project need; fails to properly consider reasonable, less damaging alternatives, and fails to examine the full suite of adverse impacts from the Project. The Draft EIS draws conclusions on the value of the proposed mitigation that are fundamentally at odds with modern science and ignores important statutory and regulatory mitigation requirements.

The Project is prohibited under the Clean Water Act 404(b)(1) Guidelines and is appropriate for a Clean Water Act Section 404(c) veto due to the severity of the harm it will cause to fishery areas and wildlife. The proposed mitigation and the mitigation plan are both scientifically unsound and legally inadequate. And, as noted above, the project is at odds with longstanding federal policy.

The Project is so environmentally destructive that it simply should not be built. The Corps should abandon the Project and select the no action alternative. Should the Corps choose to pursue the Project despite its devastating environmental impacts, the Environmental Protection Agency should veto the project under Section 404(c) of the Clean Water Act, and the Department of the Interior should refer the project to the Council on Environmental Quality pursuant to 42 U.S.C. § 4344.

II. The Project Will Cause Significant, Critical, and Unacceptable Harm to the Environmental That Cannot Be Mitigated

The Project will sever the last natural connection between the Mississippi River and its floodplain in the State of Missouri, eliminating the natural flood regime and destroying tens of thousands of acres of

¹ July 2013 Draft U.S. Fish and Wildlife Service Fish and Wildlife Coordination Act Report, DEIS Appendix Q, Part 1.

² December 27, 2002 Email from Larry Prather, then the Chief, Legislative Management Branch, U.S. Army Corps of Engineers, and currently the Corps’ Assistant Director of Civil Works (Legislation and Planning).

³ July 2013 Draft U.S. Fish and Wildlife Service Fish and Wildlife Coordination Act Report, DEIS Appendix Q, Part 1.

wetlands and vital fish and wildlife habitat. The Department of the Interior, the U.S. Fish and Wildlife Service, the Missouri Department of Conservation, and independent scientific experts have concluded that these critically significant impacts cannot be mitigated. For example:⁴

- **U.S. Department of the Interior:** the Department of The Interior has advised the Corps that the Project would have critically significant unacceptable impacts to fish and wildlife resources that cannot be mitigated.

2013 Comments on the DEIS⁵ —

“Up to 53,556 acres of functional wetlands would be degraded or eliminated by the project. Those habitats provide essential breeding and migration areas for 193 species of migratory birds, including tens of thousands of migrating shorebirds and waterfowl. The fisheries impacts have been significantly underestimated and extend far beyond the 5-year floodplain used in the analysis conducted by the Corps. Frequent Mississippi River backwater flooding (2 to 5 year intervals) during the spring is extensive and the spawning, nursery and foraging habitat (15,000 to 50,000 acres) it provides for an extremely diverse fishery (114 species representing 22 families) **is unique and irreplaceable**. Recent scientific investigations along the Missouri and Mississippi rivers show how critical less frequent, but large, flood events are in maintaining populations of long-lived, commercially important fish such as catfish, paddlefish, drum, sturgeon, and white bass. The difference between the 5 year and 20 year flood in both basins is 40,000 acres. During flood events, connected agricultural floodplains provide expansive, slackwater fish habitats that cannot be substituted by the constricted, fast-flowing main channel and adjacent batture lands. The Floodway closure and proposed pumps would eliminate 75 percent of the spring, and 95% of the fall shorebird habitat in the Floodway. It would also result in an estimated 39% loss of Duck Use Days during critical spring migration”.

“The Department continues to have significant concerns regarding potential project effects to fish and wildlife resources, as detailed in our August 26, 2011, letter to Assistant Secretary Darcy (enclosed). **In spite of our repeated concerns, current project plans are essentially unchanged from the original alternative. The project would essentially eliminate a unique landscape and ecological feature in southeast Missouri and result in the loss of thousands of acres of wetlands and their connection to the Mississippi River. At present, the Department does not believe these impacts can be adequately mitigated.**”

“Should the Corps pursue the Tentatively Selected plan, and fail to move towards a less environmentally-damaging alternative, the Department of the Interior will consider this project a candidate for referral to the Council on Environmental Quality in accordance with 40 CFR 1504.”

⁴ While a number of the conclusions outlined in this section were made prior to release of the DEIS, those conclusions remain valid as the key elements of the Tentatively Selected Plan and the fundamental approach to mitigation have not changed since those conclusions were rendered.

⁵ November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers (emphasis added).

2011 Letter to the Assistant Secretary of the Army (Civil Works)⁶—

“Unless the purpose and alternatives for the New Madrid project have changed since the last evaluation, the Department does not believe that it is in the public interest to engage in yet more environmental analysis of this project.”

“Altering the hydrologic regime of the floodway produces a suite of complex and ***unsolvable challenges*** in providing adequate mitigation for the wetland, fishery, and floodplain impacts.”

The Corps’ mitigation plans for the project “***are at odds with contemporary understanding of wetland and floodplain science and agency mitigation guidance.*** This science emphasizes the critical importance of natural hydrology, spatial extent, and landscape position. The science recognizes the importance to habitat values of subtle features of hydrology, including depth, velocity, and timing of flooding and the relationship of one habitat to another. The Corps wetland mitigation guidance specifically endorses these principles.”

- **U.S. Fish and Wildlife Service:** Through a series of Fish and Wildlife Coordination Act reports, the Fish and Service has advised the Corps that the Project would have critically significant unacceptable impacts to fish and wildlife resources that cannot be mitigated.

2013 Draft Fish and Wildlife Coordination Act Report⁷—

“The project would essentially eliminate a unique landscape and ecological feature in southeast Missouri and result in loss of thousands of acres of wetlands and their connection to the Mississippi River that ***cannot be adequately mitigated***. This would occur as a result of a project with vaguely defined crop optimization benefits on some portions of both basins.”

The Service opposes the New Madrid Floodway component of the preferred alternative because it would “***cause substantial, irretrievable losses of nationally significant fish and wildlife resources, and greatly diminish rare and unique habitats found in southeast Missouri.***” The Service further concludes that “***project-related wetlands losses are at odds with the federal conservation policy goals and sustainable water resources development.***”

“The TSP will eliminate spring overbank flooding that currently may cover tens of thousands of acres in the St. Johns Bayou basin and the New Madrid Floodway. Upon receding, those flood waters produce thousands of acres of shallow, temporarily flooded wetlands in a variety of cover types. A variety of waterfowl, numerous other wetland dependent birds, amphibians, invertebrates, and mammals benefit from those habitats. Some of the largest remaining forested wetland tracts in southeast Missouri are found in the project area and would be negatively affected by the TSP. Seasonal backwater flooding in the New Madrid Floodway provides important floodplain habitat

⁶ August 26, 2011 Letter from Acting Assistant Secretary for Fish Wildlife and Parks to Assistant Secretary of the Army for Civil Works (emphasis added).

⁷ DEIS Appendix Q, Part 1 (emphasis added).

that supports an extremely abundant and diverse fish fauna (both floodplain and riverine), some of which are becoming regionally scarce. The interchange between the Floodway and the river supports a sustainable ecosystem not found elsewhere along the Mississippi River in Missouri. Alterations in the extent and timing of seasonal flooding in the project area greatly concern the Service not only because of adverse impacts upon numerous Federal and State trust resources, but also because of the potential adverse impacts to the study area ecosystem and cumulative impacts in the Lower Mississippi Valley.”

“The Corps has proposed reforesting 9,423 acres of frequently flooded croplands (i.e. farmed wetlands) near the project area to compensate for project-related fish and wildlife habitat losses. That plan, however, would result in a net loss of wetland acreage and functions within the project area, and a regional net loss of wetland acreage. In addition, although the proposed mitigation measures would compensate losses of wetland habitat value, they would not mitigate impacts to floodwater storage, nutrient cycling or detrital export/import, and water quality changes. Fish and wildlife species with limited mobility (i.e., reptiles, amphibians, and larval fishes) will experience a net loss of habitat within the project area that may not be compensated through the proposed mitigation lands. For those reasons, the Service urges the Corps to pursue measures to avoid project impacts rather than try to compensate for them after the fact.”

2006 Fish and Wildlife Coordination Act Report⁸—

The Mississippi River-New Madrid Floodway **“connection is absolutely vital to maintaining a healthy, sustainable fishery in this section of the Mississippi River. Completing the closure of the New Madrid Floodway will eliminate a major area of river-floodplain connectivity in this region of the River and the very last area of its kind in the State of Missouri.”**

“The exceptional value of backwater areas of the Mississippi River to the River’s regional fishery and on-going threats to these backwater areas requires that we continue to explore and implement mitigation measures that avoid and minimize further losses. **The Service is unaware of any feasible mitigation techniques that can provide in-kind replacement to offset the permanent loss of this habitat and associated ecological processes.** . . . “The Services’ position on this issue has not changed from our previous FWCA Reports.”

2002 Fish and Wildlife Coordination Act Report⁹—

The project **“will result in significant losses of regionally and nationally important fish and wildlife resources which can not be adequately mitigated due to project design and economic objectives.”**

⁸ March 15, 2006 U.S. Fish and Wildlife Service Supplemental Fish and Wildlife Coordination Act Report (included at pages 510-515 of the Revised Supplemental Environmental Impact Statement Number 2 for the St. Johns Bayou-New Madrid Floodway Project) (emphasis added).

⁹ June 6, 2002 U.S. Fish and Wildlife Service Supplemental Fish and Wildlife Coordination Act Report at E-2, E-9 (Consolidated 2009 NEPA Appendix E 11) (emphasis added). The Consolidated 2009 NEPA Appendix is available at http://www.mvm.usace.army.mil/stjohns/2009_update/IEPR_Documents/4f_App_E_FWCAR.pdf.

The project “will significantly reduce the duration and frequency of flooding on 130,000 acres of Mississippi River floodplain, adversely impact a regionally important fishery (including an economically viable commercial fishery) by eliminating the last remaining connection of the Mississippi river with its historic floodplain in Missouri, result in the elimination or major degradation of over 18,000 acres of wetland habitat and their ecological functions, and cause further decline in the biological and ecological integrity of a federally designated National Natural Landmark. . . . The project, as presently formulated, provides only superficial consideration of fish and wildlife resources”

“The proposed project design actions and changes **do nothing to avoid** fish and wildlife resource losses and the minimization features are nominal considering the significant scope and magnitude of these losses.”

2000 Fish and Wildlife Coordination Act Report¹⁰—

Even with mitigation the project “**would cause substantial, irretrievable losses of nationally significant fish and wildlife resources, and greatly diminish rare and unique habitats in southeast Missouri.**”

- **U.S. Environmental Protection Agency:** EPA’s Region 7 Watershed Planning & Implementation Branch Manager has said that the Project “**could potentially have the largest negative impact on wetlands and streams of any project ever proposed in Region 7.** The proposed plan will close a 1,500 ft. levee gap along the New Madrid Floodway, the last levee gap for the Mississippi River in Missouri.”¹¹
- **Missouri Department of Conservation:** The Missouri Department of Conservation has advised the Corps and the Fish and Wildlife Service that the Project is unacceptable and that the Project’s impacts cannot be mitigated.

2002 Letter to the U.S. Fish and Wildlife Service¹²—

“We concur with your comment that levee closure and gate operation 3-1B [the alternative selected by the Corps] is unacceptable given that it makes no more than a token effort to mitigate fish and wildlife losses.”

2001 Letter to the Corps of Engineers¹³—

“The loss of connectivity between the floodplain and the Mississippi River is the single most significant project feature and **its loss cannot, in reality, be mitigated.**”

“As stated previously, the single most significant project impact to the aquatic resources is the major reduction in the magnitude of seasonal flooding and connectivity to the

¹⁰ May 2000 U.S. Fish and Wildlife Service Fish and Wildlife Coordination Act Report at v (Consolidated 2009 NEPA Appendix E 63) (emphasis added).

¹¹ February 23, 2011 Email from EPA Region 7 Watershed Planning & Implementation Branch Manager.

¹² July 15, 2002 Letter from John Hoskins, Director of the Missouri Department of Conservation to Charles Scott, Field Supervisor, Missouri Ecological Services Field Office, U.S. Fish and Wildlife Service.

¹³ December 15, 2001 Letter from Jerry Conley, Director Missouri Department of Conservation to Colonel Scherer, Memphis District Engineer, U.S. Army corps of Engineers (emphasis added).

Mississippi River. Levee closure in the New Madrid Floodway and pump operations will eliminate backwaters from covering the floodway and bayou basins. Connectivity between the Mississippi River and the floodplain provides important ecological interactions and **cannot be mitigated for** in this project. Many species of fish move from the river into the floodplain in the spring to spawn. The gap closure will prevent that exchange."

The project "will cause major declines in wetlands, their functions and inhabitants; fish spawning and rearing; mussels, birds and waterfowl feeding sites during migration."

- **Independent Expert Joy Zedler, PH.D:** In 2006 and again in 2013, Dr. Joy Zedler, Professor of Botany and Aldo Leopold Chair in Restoration Ecology at the University of Wisconsin and Chair of the National Research Council Panel on *Compensating for Wetland Losses Under the Clean Water Act*, concluded that the mitigation proposed by the Corps for the Project is both scientifically unsound and environmentally harmful.

The claim that the proposed mitigation for the St. Johns - New Madrid Floodway Project "fully offsets project impacts on aquatic resources is **completely inconsistent with scientific understanding** of wetland functioning, wetland replacement, wetland restoration, and mitigation of other aquatic areas, as well as inconsistent with established practice under the Section 404 program. **The claim is so outside the range of reasonable scientific understanding that it cannot be seriously advanced as science-based.** It therefore should be disregarded."¹⁴

"The Corps' claim for this project that the loss of a vast area of seasonally flooded aquatic habitat could be replaced by unnaturally extended flooding on a small area of already existing wetlands would be **an extreme example of what the NRC report recommended against.**"¹⁵

For the St. Johns New Madrid Floodway Project, "the Corps has proposed to do the opposite of [the National Academy of Sciences recommendations on mitigation]. It would dramatically reduce or eliminate flooding according to a relatively natural pattern on tens of thousands of acres of wetlands and other valuable floodplain areas, and replace them primarily by artificially manipulating the hydrology on a small number of acres of already existing wetlands. **According to established understanding, that mitigation should itself be viewed as harmful, and according to accepted scientific understanding, it cannot offset the impacts of this project.**"¹⁶

- **Independent External Peer Review Panel:** The independent panel of experts convened to evaluate the DEIS concluded that the Project would cause significant cumulative impacts.

¹⁴ January 2006 Report of Dr. Joy Zedler on the Mitigation Proposal for the St. Johns Bayou/New Madrid Floodway Project at 3, 5, 7 (emphasis added); November 25, 2013 REPORT OF DR. JOY ZEDLER ON DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE ST. JOHNS BAYOU/NEW MADRID FLOODWAY PROJECT (2013). A copy of Dr. Zedler's 2006 and 2013 reports are attached to these comments at Attachment B.

¹⁵ *Id.*

¹⁶ 2006 Zedler Report.

IEPR Phase 3¹⁷ —

“The DEIS assigns little value to the ecosystem services (e.g., carbon sequestration) provided by floodplain connection to the Mississippi River, based on the argument that the system has been significantly changed over time. However, the Panel believes that the ecological value of the remaining connection to the Mississippi River is high. As described in CEQ (1997), the loss of this last remaining connection is an example where additional impacts, no matter how small, will have a disproportionate cumulative effect by exceeding the threshold where floodplain connection ecosystem functioning is eliminated. **The Panel believes that closing the last connection would have a significant cumulative impact on the flood-dependent system.** While it is not required that a project compensate for historical impacts, **it is incumbent on the project not to contribute the incremental impact that may cause the project to exceed this overall threshold.**

IEPR Phase 2¹⁸ —

“The panel believes that the New Madrid Floodway is unique because, in context, it is the last remaining connection between the Mississippi River and its floodplain in the State of Missouri. Therefore, it plays a much larger role in providing natural floodplain services than the other areas. If the other originally connected areas had not been disconnected, the Floodway would be playing a proportionally smaller, and less important, role in maintaining the natural ecosystem. **The loss of this last remaining connection and its ecosystem functioning would be the “straw that broke the camel’s back” in terms of the total cumulative impact.** That is, not all incremental impacts are equal and it is the impact that exceeds a threshold that is significant. In this case, the adverse impact of removing the last floodplain connection, once the other connections have already been removed, is disproportionately high.”

III. The Project is Appropriate for a Clean Water Act Section 404(c) Veto

The environmental consequences of the Project are so significant that the Project is appropriate for a Clean Water Act Section 404(c) veto. Should the Corps adopt the Tentatively Selected Plan (TSP) or any variation of the TSP that causes similarly destructive impacts, the Conservation Organizations call on EPA to initiate – and issue – a Clean Water Act Section 404(c) veto of the Project.

Section 404(c) of the Clean Water Act authorizes the Administrator of EPA to “prohibit, restrict, or deny the specification of any defined area in waters of the United States (including wetlands) as a disposal site for the discharge of dredged or fill material whenever it determines, after notice and opportunity for public hearing, that such discharge into waters of the United States will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas.”¹⁹

¹⁷ DEIS Volume 3 Part 4, Phase III IEPR Final Comment Response Record at 61 (emphasis added).

¹⁸ DEIS Volume 3 Part 3, Phase 2 IEPR at B-43 (emphasis added).

¹⁹ Clean Water Act § 404(c), 33 U.S.C. § 1344(c).

This authority provides an important tool for protecting the nation's waters and for ensuring that EPA can effectively carry out its Clean Water Act oversight responsibilities. EPA has utilized Section 404(c) sparingly, but the impacts of the Project – particularly those on fishery areas (including spawning and breeding areas) and wildlife – are so significant that a veto is both appropriate and necessary.

As discussed in Sections II and VII of these comments, the Department of the Interior, the Fish and Wildlife Service, the Missouri Department of Conservation, and independent experts have all concluded that the Project would cause the precise types of unacceptable adverse impacts that warrant a 404(c) veto.

IV. The Project is Prohibited Under the Clean Water Act 404(b)(1) Guidelines and Conflicts with Section 10 of the Rivers and Harbors Act

Construction and operation of the Project would violate Section 404 of the Clean Water Act due to the magnitude and severity of the environmental harm that would be caused, the ability to avoid those impacts through the use of nonstructural and restoration efforts, and the Corps' failure to require adequate compensatory mitigation.

In carrying out its civil works activities, the Corps must comply with the requirements of Clean Water Act Section 404 and the Section 404(b)(1) Guidelines.²⁰ Critically, the 404(b)(1) Guidelines **prohibit** the Corps from proceeding with the Project if:

- (a) The project "will cause or contribute to significant degradation of the waters of the United States;"²¹ or
- (b) A less damaging practicable alternative is available;²² or
- (c) The project fails to adequately minimize and compensate for wetland and other aquatic resource losses;²³ or
- (d) The project evaluation fails to establish that the project will not have unacceptable adverse environmental impacts.²⁴

The TSP is prohibited under each of these mandates.

A. The Project Would Cause or Contribute to Significant Degradation of Waters of the United States

The TSP would cause and contribute to significant degradation of waters of the United States. Under the 404(b)(1) Guidelines, effects that contribute to significant degradation include:

- Significantly adverse effects of the discharge of pollutants on human health or welfare, including but not limited to effects on . . . fish, shellfish, wildlife, and special aquatic sites;

²⁰ 33 U.S.C. § 1323; 33 C.F.R. § 336.1(a).

²¹ 40 C.F.R. § 231.10(c).

²² 40 C.F.R. § 230.10(a).

²³ See 40 C.F.R. 230.10(a)–(d).

²⁴ 40 C.F.R. § 230.1(c).

- Significantly adverse effects of the discharge of pollutants on life stages of aquatic life and other wildlife dependent on aquatic ecosystems;
- Significantly adverse effects of the discharge of pollutants on aquatic ecosystem diversity, productivity, and stability. Such effects may include, but are not limited to, loss of fish and wildlife habitat or loss of the capacity of a wetland to assimilate nutrients, purify water, or reduce wave energy; or
- Significantly adverse effects of discharge of pollutants on recreational, aesthetic, and economic values.²⁵

As discussed above, the adverse impacts of the Project are so dire that they unquestionably would cause or contribute to significant degradation of the nation's waters. The TSP would cause significant and severe impacts to virtually every factor identified above and would cause unacceptable adverse impacts to fish and wildlife habitat and special aquatic sites, including wetlands.

Because it would cause or contribute to significant degradation of the nation's waters, the TSP is prohibited by the 404(b)(1) Guidelines.

B. Less Damaging, Practicable Alternatives Are Available

The assessment and evaluation of the existence of less damaging reasonably practicable alternatives may not be constrained by the existence of a Congressionally authorized plan. To the contrary, to comply with the Clean Water Act an evaluation of reasonably practicable alternatives must include a review of alternatives outside of the jurisdiction of the Corps, including alternatives that are outside of the scope of a Congressionally authorized project.²⁶ The Corps' limited analysis of less damaging alternatives is fundamentally flawed. The Corps relied on flawed cost and economic analyses as the sole basis for eliminating most of the low impact solutions it considered. The many problems with the Corps' economic analysis are discussed in Section VII.D. of these comments. The Corps also failed to evaluate a number of important and viable low impact alternatives at all.

In addition to these problems, when the Corps did look at alternatives in combination, the Corps typically combined less costly alternatives with more costly alternatives (e.g., road elevations, ring levees, etc) raising the cost of the combined alternatives. The Corps improperly rejected the crop conversion alternatives (agriculture to silviculture, and conversion flood tolerant crops) on the basis of the cost of enrolling lands in the WRP program. This is entirely inappropriate as: (1) the costs of enrolling in WRP are completely unrelated to the costs of conversion to an alternative flood tolerant crop; and (2) WRP lands cannot be utilized to produce crops that can be sold in the marketplace. Crop conversion alternatives would result in the production of crops or trees that can be sold for a profit which would fundamentally alter the benefit cost analysis for such alternatives. Because of these and

²⁵ 40 C.F.R. § 230.10(c).

²⁶ *E.g.*, 40 C.F.R. § 230.2(a)(2) (the 404(b)(1) Guidelines are applicable to the Corps' civil works program); 40 C.F.R. § 230.10(a)(2) (an "alternative is practicable if it is available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes. If it is otherwise a practicable alternative, an area not presently owned by the applicant which could reasonably be obtained, utilized, expanded or managed in order to fulfill the basic purpose of the proposed activity may be considered."). As discussed in Section IV.B. and VII.C. of these comments, NEPA also requires the Corps to rigorously evaluate all reasonable alternatives, including those outside of the Corps' jurisdiction.

many other problems, the Corps' alternatives analysis is inadequate to determine whether less damaging practicable alternatives are available.

The activities outlined below, either individually or in combination, constitute reasonably practicable alternatives that would provide extensive flood damage reduction benefits while also protecting the environment and providing benefits to the public at large. While the Corps included a cursory review of a small number of these activities in the DEIS, it failed to consider or evaluate most of these activities and failed to consider any alternatives that included a combination of some or all of these activities:

1. Purchase of additional flowage easements in the New Madrid Floodway and/or modification of the terms of existing flowage easements to provide a more meaningful degree of compensation for smaller floods – the Federal Government currently owns flowage easements on at least 111,840 acres of land in the New Madrid Floodway;²⁷
2. Purchase of perpetual conservation easements on both cleared and forested lands in the Project area;
3. Accelerated use of Wetlands Reserve and Conservation Reserve Programs in the Project area;
4. Floodplain and wetland restoration in the Project area;
5. Creation and/or expansion of fish and wildlife refuges in the Project area;
6. Reintroduction of historic Mississippi River backwater flows into Big Oak Tree State Park as a project element (or as a stand-alone project) instead of as mitigation;
7. Economic stimulus focused on promoting conversion of existing agriculture to flood tolerant silviculture;
8. Economic stimulus aid for East Prairie;
9. Targeted flood proofing and small scale flood protection projects as necessary to protect East Prairie and other communities or structures at risk from flooding, including targeted elevation of homes, businesses and roads, and voluntary relocation;
10. Sewer and water infrastructure improvements for East Prairie;
11. Water quality monitoring and water quality education;
12. Nutrient trading

In addition to the many alternatives discussed above, reasonably practicable alternatives include the use of flood hazard mitigation options for flood prone structures. Such programs are currently available to the State of Missouri, local communities, and individual residents and businesses in the Project Area. These include programs available under: (a) the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988,²⁸ including the Stafford Act's Hazard Mitigation Grants Program²⁹; (b) the National Flood Insurance Program (NFIP)³⁰, including the NFIP's Flood Mitigation Assistance and Severe

²⁷ By 1942, the Federal government had purchased flowage easements on 106,858 acres of land in the New Madrid Floodway. By 1974, the Federal government had purchased modified flowage easements on 80,982 acres in the New Madrid Floodway, including 76,000 acres that were under the originally purchased easements. Mississippi River Commission Information Paper, *Mississippi River & Tributaries Project: Birds Point-New Madrid Floodway*, at 7, 11. The St. John Levee and Drainage District also appears to own easements covering 57,000 acres within the backwater area. *Id.* at 10.

²⁸ 42 U.S.C. 5121-5207, P.L. 93-288, as amended, particularly through the "Public Assistance Program" and the "Section 404 Hazard Mitigation Grants Program."

²⁹ 42 U.S.C. § 5170c.

³⁰ 42 U.S.C. Chapter 50.

Repetitive Loss Programs³¹; and (c) the Federal Emergency Management Agency's Pre-Disaster Mitigation Program³² (the PDM Program) and Public Assistance program (which is also part of the Stafford Act).

These programs provide funding, both before and after flood disasters, for mitigation of flood risks to residences, businesses, and public facilities (including roads and utilities). The Hazard Mitigation Grants Program provides an additional 15 percent beyond FEMA's total expenditures of Stafford Act disaster assistance grants in any Presidentially-declared disaster (with limitations for costs above \$2 billion per disaster declaration) for investments through the affected State in FEMA-approved hazard mitigation activities. The money is available as a 75 percent grant for generally non-structural hazard mitigation, such as voluntary buyout acquisitions and relocation or demolition of floodprone properties and dedication of related lands to permanent open space condition, and elevation and/or floodproofing of structures.

In addition, all FEMA flood insurance policies include an "Increased Cost of Construction" insurance rider that provides up to \$30,000 of coverage that can be used for post-flood building elevations or otherwise for bringing buildings up to current code requirements and elevation standards. Funds paid out under this insurance rider provide substantial funding that can be applied directly as the non-Federal match for hazard mitigation costs to elevate properties at least to the base flood elevation (1 percent chance annual flood).

The State of Missouri has had important successes in utilizing buyouts and relocations to protect communities and avoid flood damages.³³ The state also recently adopted a new State Hazard Mitigation Plan that highlights the high priority that Missouri places on the state's voluntary buyout program.³⁴ The new Hazard Mitigation Plan makes **no** mention of constructing new levees to protect agricultural lands, but instead talks extensively about the dangers of levee failures and overtoppings.

³¹ 42 U.S.C. § 4104c.

³² FEMA's PDM Program was added to the Stafford Act (42 U.S.C. 5165) in 2000, enacted under section 104 of the Disaster Mitigation Act of 2000 as amended, P.L. 106-390.

³³ Missouri State Emergency Management Agency, *Stemming the Tide of Flood Losses* (available at <http://sema.dps.mo.gov/docs/publications/stemming.pdf> last visited November 11, 2013); Missouri State Emergency Management Agency, *Out of Harm's Way: The Missouri Buyout Program*, 1995, p.5. FEMA realized a 99 percent savings from the Missouri Buyout Program in St. Charles, Co., MO, when in May, 1995, less than two years after the 1993 Great Midwest Flood (which in 1993 cost FEMA \$26 million), the St. Charles County buyout area was again subject to major flooding.

³⁴ Missouri State Hazard Mitigation Plan July 2013 (available at http://sema.dps.mo.gov/docs/programs/Logistics,%20Resources,%20Mitigation%20&%20Floodplain/mitigation/MO_Hazard_Mitigation_Plan_2013.pdf last visited November 11, 2013) ("Missouri's voluntary flood buyout program was established after the Great Flood of 1993. Since then, over 4,500 primary residences have been acquired, which allows households in flood-prone areas to voluntarily relocate out of harm's way. The acquired properties are then placed in public ownership with deed restrictions that ensure that future use of that land will not put people and property at risk to flooding disasters. The buyout program uses a mixture of funds sources, including the Hazard Mitigation Assistance grants, Public Assistance, Community Development Block Grant Program, and some financial assistance from The Salvation Army and the Interfaith Disaster Response funds. The Community Buyout Program was recognized as a model for the nation following the devastating 1993 floods. Local communities throughout the State have continued this program by using their own funds to acquire flood-prone properties. Because of the success of this program, acquisition of flood-prone structures continues to be a priority for hazard mitigation funding in the State and in particular, the acquisition of repetitive loss structures under NFIP.")

Because less damaging, practicable alternatives are available, the TSP is prohibited by the 404(b)(1) Guidelines.

C. The Project Fails To – And Cannot – Adequately Minimize and Compensate for the Wetland and River-Floodplain Connectivity Losses Caused by the Project

The adverse environmental impacts of all projects not otherwise prohibited by the 404(b)(1) Guidelines must be minimized to the maximum extent practicable. To this end, impacts must first be avoided if at all possible. Impacts that cannot be avoided are to be minimized by modifying the project. If modification is not possible, the impact is to be rectified by restoring the environment.³⁵

As discussed throughout these comments, the TSP is so environmentally destructive that it is prohibited under the 404(b)(1) Guidelines and should not be recommended or constructed by the Corps. The Corps has also not taken the steps needed to avoid, minimize and mitigate for the adverse impacts of the Project. For example, as discussed above, the Corps could avoid all adverse impacts of this project by selecting an alternative that consists of one or more wholly non-structural activities, or an alternative that consists of a combination of nonstructural and restoration activities, to reduce flood damages.

The Corps also has not minimized the impacts of this project. It could have done this by selecting a less damaging operating regime (we note, however, that even a less damaging operating regime would produce so much harm that the Project would be prohibited under the 404(b)(1) Guidelines). The Corps has also ignored important Fish and Wildlife Service recommendations that would help minimize the adverse impacts of the Project. To minimize the adverse impacts, the Corps should, at a minimum, adopt the recommendations set forth at pages 50 through 53 of the July 2013 Draft Fish and Wildlife Coordination Act Report found in Appendix Q Part 1. Should the Corps opt to proceed with recommending the TSP or a variation of the TSP in its final EIS, the Corps should also adopt any additional recommendations for minimizing impacts included in the final Fish and Wildlife Coordination Act report and such recommendations included in the comments submitted by any other federal or state agencies, independent experts, and members of the public.

Finally, as is discussed in detail in Section V of these comments, the compensatory mitigation proposed by the Corps is woefully inadequate and the mitigation “plan” contained in the DEIS fails to comply with fundamental legal requirements. Critically, federal and state agencies and experts have all concluded that the adverse impacts of the Project cannot be mitigated.

Because the Corps has failed to – and cannot – adequately minimize and compensate for the adverse impacts that the Project would cause to the nation’s waters, the TSP is prohibited by the 404(b)(1) Guidelines.

D. The Corps Has Not Carried Out the Review Necessary to Demonstrate that the Project Will Not Have Unacceptable Adverse Environmental Impacts

It is a “fundamental precept” of the 404(b)(1) Guidelines that “fill material should not be discharged into the aquatic ecosystem, unless it can be demonstrated that such a discharge will not have an

³⁵ 40 C.F.R. § 230.10(d).

unacceptable adverse impact either individually or in combination with known and/or probable impacts of other activities affecting the ecosystems of concern.” 40 C.F.R. § 230.1(c). To make this assessment, the Corps must:

- Determine “the nature and degree of effect that the proposed discharge will have, both individually and cumulatively, on the structure and function of the aquatic ecosystem and organisms.” 40 C.F.R. § 230.11(e).
- “Determine the nature and degree of effect that the proposed discharge will have, individually and cumulatively” on a number of factors, including “water, current patterns, circulation including downstream flows, and normal water fluctuation” and “the structure and function of the aquatic ecosystem and organisms.” 40 C.F.R. §230.11(b) and (e).
- Consider secondary impacts, which are “effects on an aquatic ecosystem that are associated with a discharge of dredged or fill materials, but do not result from the actual placement of the dredged or fill material.” 40 C.F.R. §230.11(h).
- Consider the impacts described in 40 C.F.R. § 230.10(c) to determine whether the project would cause or contribute to significant degradation of the waters of the United States, and would thus be prohibited.³⁶

As discussed throughout these comments and in the November 18, 2013 Comments by the Department of the Interior,³⁷ the Corps has not properly carried out these necessary evaluations, and has not accounted for the full range of aquatic impacts. For example, the DEIS fails to evaluate the impacts to wetlands and fish and wildlife from hydrologic changes above the 5 year floodplain.³⁸ “This ignores effects to thousands of acres of wetlands that will have reduced inundation as a result of the project.”³⁹ The Department of the Interior “has consistently” told the Corps that the Hydrogeomorphic Method (HGM) that is used “did not include all of the potentially affected wetlands” and that the model is “insensitive to hydrological changes and other important factors.”⁴⁰ The Department of the Interior has also concluded that the DEIS “does not account for forested wetlands that will be lost as a result of being cleared due to post-project drainage and agricultural conversion” because the Corps has restricted “its evaluation to the construction footprint and does not include the reasonably foreseeable indirect effects to forested wetlands caused by the changes in land use and hydrologic changes.”⁴¹

Because the Corps has not carried out the review necessary to demonstrate that the Project will not have unacceptable adverse environmental impacts, the TSP is prohibited by the 404(b)(1) Guidelines.

³⁶ These impacts are discussed in Section IV.A. of these comments.

³⁷ November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers (emphasis added).

³⁸ The Conservation Organizations also note that while the Corps has not evaluated impacts above the 5-year floodplain it has claimed benefits above the 5-year floodplain, including for example, claiming 22% of Project benefits for avoiding the need to elevate Interstate 55, which the DEIS states is not affected by flooding until a 10 year flood and with sandbagging and other efforts can be kept open through at least a 50 year flood. See DEIS at 8-9, and Section VII.D. of these comments.

³⁹ *Id.* at Specific Comments page 6.

⁴⁰ *Id.* at cover letter page 2.

⁴¹ *Id.* at Specific Comments page 11.

E. The Project Conflicts with the Requirements of Section 10 of the Rivers and Harbors Act

Under Section 313 of the Clean Water Act, Corps projects are also subject to § 10 of the Rivers and Harbors Appropriation Act of 1899, 33 U.S.C § 403. Section 10 requires Corps authorization for filling activity or other modifications of navigable waters, such as this project on the Mississippi River. The Corps relies on a single, consolidated set of regulations to delineate permit requirements for § 10 and CWA § 404 permits.⁴² Although § 10 permits do not have to comply with the § 404(b)(1) Guidelines, they must withstand a public interest review that requires a balancing of economic goals and impacts on “wetlands”, “fish and wildlife values”, and “floodplain values”.⁴³

The TSP is prohibited under the regulatory requirements of § 10 of the Rivers and Harbors Act because the significant and unacceptable adverse impacts to wetlands, fish and wildlife values, and floodplain values vastly outweighs any potential economic gains. As a result, the project is not in the public interest as defined by applicable regulations.

V. The Proposed Mitigation is Scientifically Unsound and Legally Inadequate

There is overwhelming consensus that the significant adverse impacts of this project simply cannot be mitigated. Outside experts have also concluded that the mitigation that has been proposed is both scientifically unsound and environmentally damaging. Finally, it is undeniably clear that both the mitigation and mitigation “plan” proposed by the Corps in the DEIS fail to comply with longstanding statutory and regulatory requirements.

A. The Significant Adverse Impacts of the Project Cannot Be Mitigated

As discussed in Sections II, V, and VII of these comments, there is overwhelming consensus that the significant adverse impacts of the TSP cannot be mitigated. For example:

- The Department of the Interior has concluded that “[a]ltering the hydrologic regime of the floodway produces a suite of complex and unsolvable challenges in providing adequate mitigation for the wetland, fishery, and floodplain impacts.”⁴⁴ Mitigation plans for the project “are at odds with contemporary understanding of wetland and floodplain science and agency mitigation guidance.”⁴⁵
- The Fish and Wildlife Service has concluded that the project “would essentially eliminate a unique landscape and ecological feature in southeast Missouri and result in loss of thousands of acres of wetlands and their connection to the Mississippi River that cannot be adequately mitigated.”⁴⁶ Moreover, the Service “is unaware of any feasible mitigation techniques that can

⁴² 33 C.F.R. pts 320-330.

⁴³ 33 C.F.R. § 320.4.

⁴⁴ 2011 Department of the Interior Letter.

⁴⁵ 2011 Department of the Interior Letter.

⁴⁶ July 2013 Draft Fish and Wildlife Coordination Act Report at vi-vii, DEIS Appendix Q Part 1.

provide in-kind replacement to offset the permanent loss of this habitat and associated ecological processes.”⁴⁷

- The Missouri Department of Conservation has concluded that “[c]onnectivity between the Mississippi River and the floodplain provides important ecological interactions” and “this loss cannot be mitigated.”⁴⁸
- Dr. Joy Zedler, a renowned wetland mitigation expert has concluded that the Corps’ mitigation “should itself be viewed as harmful” and “cannot offset the impacts of this project.”⁴⁹ The Corps’ claim that the proposed mitigation “fully offsets project impacts on aquatic resources is completely inconsistent with scientific understanding of wetland functioning, wetland replacement, wetland restoration, and mitigation of other aquatic areas, as well as inconsistent with established practice under the Section 404 program.”⁵⁰

B. The Mitigation for the Project Is Fundamentally the Same as the Mitigation That Has Already Been Struck Down by the Courts

One of the striking features of the succession of the different environmental impact statements for this Project, including the DEIS, is that the general types and quantity of mitigation continue not to change despite the fundamental flaws showed in the previous mitigation.

- In the first two rounds of environmental impact statements, including the one completed in 2002, the mitigation was roughly 9,000 acres of which 8,375 were reforestation lands. In court, conservationists demonstrated among other things that the calculation of this 8,375 acres of total inundation was based on a math error. In fact, the calculation required that this many acres be flooded on average every day during the fish-midseason (*i.e.*, 8,375 average daily flooded acres). For example, if a typical acre of mitigation were flooded 25 percent of the time in the midseason, the true mitigation required was 33,500 acres of reforestation. After conceding the error, the Justice Department compelled the Corps to withdraw the EIS.
- The next round of EIS came up with almost exactly the same total mitigation. It conceded that virtually all the reforestation areas would be dry most of the time and would collectively produce less than 10 percent of the needed mitigation. The overwhelming bulk of the mitigation was then declared to be provided by the sump area, which would be managed to be flooded a little longer, and as a result was called a “permanent water body” even though it would still be only seasonally flooded and in fact only modestly more flooded than otherwise. (The management would also further restrict fish access). That plan was struck down by the District Court as arbitrary and capricious.

⁴⁷ 2006 FWCA Report.

⁴⁸ December 15, 2001 Letter from Jerry Conley, Director Missouri Department of Conservation to Colonel Scherer, Memphis District Engineer, U.S. Army Corps of Engineers.

⁴⁹ January 2006 Report of Dr. Joy Zedler on the Mitigation Proposal for the St. Johns Bayou/New Madrid Floodway Project at 3, 5, 7 (2006 Zedler Report). Dr. Zedler is a Professor of Botany and Aldo Leopold Chair in Restoration Ecology at the University of Wisconsin. Dr. Zedler chaired the National Research Council Panel on *Compensating for Wetland Losses Under the Clean Water Act*.

⁵⁰ 2013 Zedler Report; 2006 Zedler Report (the conclusions in the 2006 Zedler Report remain valid as the Corps fundamental approach to mitigation for this project has not changed).

- The DEIS nevertheless still comes up with roughly the same 9,000 acres of mitigation. In this case, it does so largely by declaring that mitigation previously either in the plan or rejected would now produce vast quantities of habitat.
 - For example, Big Oak Tree State Park is supposed to provide roughly half of all fish habitat mitigation for the New Madrid Floodway although earlier versions of the EIS conceded that fish access was problematic and should not be counted. Nothing has changed technically to alter that problem.
 - Batture lands are to provide most of the remaining fish habitat although previous versions of the EIS only had modest plans for batture lands, conceding that most would not provide suitable habitat.
 - The value of floodplain lakes is recalculated in ways that minimize the impacts of the project and greatly exaggerate the benefits of mitigation, so much so that a few hundred acres of mitigation are claimed to more than offset the impacts on more than 7,000 acres of seasonally flooded forest and tens of thousands of acres of flooded agricultural lands and farmed wetlands.
 - Shorebird mitigation is now to be provided by claiming benefits for 10 Mile Pond, a conservation area that has long existed and that the Corps never claimed benefits for in the past.
 - The waterfowl calculation previously made an even larger error than the fish math error. That has been addressed in effect by dramatically reducing the estimated value of flooded agricultural land (even though it could easily produce corn and have very large values over the 50 year time period of the project), and by altering the hydrologic measure such that reduced flooding duration counts very little.

The very fact that the Corps never claimed these kinds of benefits from already proposed and possible mitigation sites by itself should cast serious doubts on the new claims of benefits. The Reports by Dr. Joy Zedler, Dr. Bruce Dugger and Dr. Richard Sparks, summarized below, explain why these new forms of mitigation do not produce the mitigation claimed. These reports also demonstrate that the Project will in fact have unacceptable adverse effects on fishery areas (including spawning and breeding areas) and wildlife, making the Project appropriate for a 404(c) veto.⁵¹

C. The Proposed Mitigation is Insufficient as a Matter of Law

Corps water projects must comply with two sets of mitigation standards. The Corps must meet the statutory mitigation requirements established specifically for Corps projects in the Water Resources Development Acts, and the Corps must meet the mitigation requirements of the Clean Water Act Section 404 program, including those established in 33 C.F.R. Part 332. The mitigation proposed in the DEIS fails utterly to comply with these requirements.

The Water Resources Development Acts establish minimum standards for civil works project mitigation, establish timing requirements for the implementation of mitigation, define the elements that must be included in mitigation plans, require the Corps to monitor civil works mitigation until ecological success is achieved, and require the Corps to consult yearly with state and federal resource agencies on the

⁵¹ Clean Water Act § 404(c), 33 U.S.C. § 1344(c).

progress being made for each civil works mitigation plan.⁵² Since enactment of the Water Resources Development Act of 2007, these mitigation mandates must be satisfied for all new and ongoing Corps project studies, and must be satisfied anytime the Corps prepares a supplemental environmental impact statement or reevaluation of a project that has already been authorized for construction.⁵³ As a result, these mitigation requirements must be met for the Project.

Mitigation Requirements Established Under the Water Resources Development Acts

The Water Resources Development Acts establish specific mitigation requirements for Corps civil works projects. Harm to bottomland hardwood forests from Corps civil works project must be mitigated in-kind, and harm to other habitat types must be mitigated “to not less than in-kind conditions, to the extent possible.”⁵⁴

Mitigation lands for Corps civil works projects must be purchased before any construction begins.⁵⁵ Any physical construction required for purposes of mitigation should also be undertaken prior to project construction but must, at the latest, be undertaken “concurrently with the physical construction of such project.”⁵⁶

Corps mitigation must be monitored until the monitoring demonstrates that the ecological success criteria established in the mitigation plan have been met. The Corps is also required to consult yearly on each project with the appropriate Federal agencies and the states on the status of the mitigation efforts. The consultation must address the status of ecological success on the date of the consultation, the likelihood that the ecological success criteria will be met, the projected timeline for achieving that success, and any recommendations for improving the likelihood of success.⁵⁷

The mitigation plan requirements established by the Water Resources Development Act of 2007 are discussed below.

Mitigation Requirements Established Under the Clean Water Act

Specific compensatory mitigation requirements under the Clean Water Act are set forth at 33 C.F.R. Part 332. These rules impose the following **additional** requirements on mitigation for Corps civil works projects:

1. Mitigation must compensate for the aquatic resource functions that will be lost to the project, and “must be commensurate with the amount and type of impact” caused by the

⁵² WRDA 2007 § 2036. These provisions have been codified at 33 U.S.C. §§ 2283, 2283a, and 2317b.

⁵³ 33 U.S.C. § 2283(d)(1)(“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 (A) a recommendation with a specific plan to mitigate fish and wildlife losses created by such project**”)(emphasis added).

⁵⁴ 33 U.S.C. § 2283(d).

⁵⁵ 33 USC § 2283(a)(“mitigation, including acquisition of the lands or interests” needed to carry out mitigation “shall be undertaken or acquired before any construction of the project . . . commences, or . . . shall be undertaken or acquired concurrently with lands and interest in lands for project purposes . . . except that physical construction required for the purposes of mitigation may be undertaken concurrently with the physical construction of such project.”)

⁵⁶ *Id.*

⁵⁷ 33 U.S.C. § 2283(d).

project.⁵⁸ Mitigation also “should provide, where practicable, the suite of functions typically provided by the affected aquatic resource.”⁵⁹

2. The mitigation “project site must be ecologically suitable for providing the desired aquatic resource functions.” In determining the ecological suitability of the compensatory mitigation site, the Corps “must consider, to the extent practicable”: the hydrological conditions, soil characteristics, and other physical and chemical characteristics; watershed-scale features including aquatic habitat diversity and habitat connectivity; and the size and location of the compensatory mitigation site relative to hydrologic sources (including the availability of water rights) and other ecological features.⁶⁰
3. Mitigation should be in kind if possible and where out of kind mitigation is utilized, the record must explain why.⁶¹
4. The Corps “must require a mitigation ratio greater than one-to-one where necessary to account for the method of compensatory mitigation (e.g., preservation), the likelihood of success, differences between the functions lost at the impact site and the functions expected to be produced by the compensatory mitigation project, temporal losses of aquatic resource functions, the difficulty of restoring or establishing the desired aquatic resource type and functions, and/or the distance between the affected aquatic resource and the compensation site. The rationale for the required replacement ratio must be documented in the administrative record for the permit action.”⁶²
5. Preservation can only be used to provide compensatory mitigation when all the following criteria are met: “(i) The resources to be preserved provide important physical, chemical, or biological functions for the watershed; (ii) The resources to be preserved contribute significantly to the ecological sustainability of the watershed. In determining the contribution of those resources to the ecological sustainability of the watershed, the district engineer must use appropriate quantitative assessment tools, where available; (iii) Preservation is determined by the district engineer to be appropriate and practicable; (iv) The resources are under threat of destruction or adverse modifications; and (v) The preserved site will be permanently protected through an appropriate real estate or other legal instrument (e.g., easement, title transfer to state resource agency or land trust).⁶³
6. “The aquatic habitats, riparian areas, buffers, and uplands that comprise the overall compensatory mitigation project must be provided long-term protection through real estate instruments or other available mechanisms, as appropriate.”⁶⁴
7. The compensatory mitigation requirements must be clearly stated and include special conditions that “must be enforceable.” The special conditions must: “(i) Identify the party responsible for providing the compensatory mitigation; (ii) Incorporate, by reference, the final mitigation plan approved by the district engineer; (iii) State the objectives, performance standards, and monitoring required for the compensatory mitigation project, unless they are provided in the approved final mitigation plan; and (iv) Describe any required financial assurances or long-term management provisions for the compensatory

⁵⁸ 33 C.F.R. § 332.3(a).

⁵⁹ 33 C.F.R. § 332.3(c).

⁶⁰ 33 C.F.R. § 332.3(d).

⁶¹ 33 C.F.R. § 332.3(e).

⁶² 33 C.F.R. § 332.3(f).

⁶³ 33 C.F.R. § 332.3(h).

⁶⁴ 33 C.F.R. § 332.7(a).

mitigation project, unless they are specified in the approved final mitigation plan....”⁶⁵ “The special conditions must clearly indicate the party or parties responsible for the implementation, performance, and longterm management of the compensatory mitigation project.”⁶⁶

8. To the maximum extent practicable, compensatory mitigation must be implemented “in advance of or concurrent with the activity” causing the impacts. “The district engineer shall require, to the extent appropriate and practicable, additional compensatory mitigation to offset temporal losses of aquatic functions that will result from the permitted activity.”⁶⁷
9. The district engineer shall require sufficient financial assurances to ensure a high level of confidence that the compensatory mitigation project will be successfully completed, in accordance with applicable performance standards.”⁶⁸
10. “For compensatory mitigation projects on public lands, where federal facility management plans or integrated natural resources management plans are used to provide long-term protection, and changes in statute, regulation, or agency needs or mission results in an incompatible use on public lands originally set aside for compensatory mitigation, the public agency authorizing the incompatible use is responsible for providing alternative compensatory mitigation that is acceptable to the district engineer for any loss in functions resulting from the incompatible use.”⁶⁹

Importantly, these mitigation requirements also make it clear that compensatory mitigation projects should be designed to be self-sustaining and should minimize the use of pumps and other active engineering features:

“Compensatory mitigation projects shall be designed, to the maximum extent practicable, to be self-sustaining once performance standards have been achieved. This includes minimization of active engineering features (e.g., pumps) and appropriate siting to ensure that natural hydrology and landscape context will support long-term sustainability. Where active long-term management and maintenance are necessary to ensure long-term sustainability (e.g., prescribed burning, invasive species control, maintenance of water control structures, easement enforcement), the responsible party must provide for such management and maintenance. This includes the provision of long-term financing mechanisms where necessary....”⁷⁰

The mitigation plan requirements established under the Clean Water Act are discussed below.

As specifically set forth specifically in the attached Reports by Dr. Joy Zedler, Dr. Bruce Dugger and Dr. Richard Sparks (and as summarized in Section VII of these comments) the mitigation proposed in the DEIS will **not** mitigate the impacts of the Project and will **not** produce the habitat and other values claimed in the DEIS. The content of each of these Reports is incorporated by reference into these comments as though fully set forth herein.

⁶⁵ 33 C.F.R. § 332.3(k).

⁶⁶ 33 C.F.R. § 332.3(l).

⁶⁷ 33 C.F.R. § 332.3(m).

⁶⁸ 33 C.F.R. § 332.3(n).

⁶⁹ 33 C.F.R. § 332.7(a).

⁷⁰ 33 C.F.R. § 332.7(b).

The Department of the Interior also identifies the following problems with the proposed mitigation for Big Oak Tree State Park:

As described, the proposed mitigation [for Big Oak Tree State Park] appears mischaracterized in the DEIS and is likely infeasible. MDNR staff has indicated the proposed restoration project, if successful, would only offset effects to the park from construction of the Floodway closure and pumping stations and it would not compensate for resource losses outside the park. In addition, because the park sits in a depression, acquisition of a minimum of 1800 acres (the rest of the depression) immediately adjacent to the park is necessary for a functional restoration project. Without it, MDNR staff notes the project would not be implementable. As pointed out previously, and as this document notes, the desire of landowners in the project area is agricultural intensification. Given increased post-project drainage coupled with high commodity prices, purchase of these lands is unlikely. Moreover, a gravity fed culvert/water delivery system should not be characterized as mimicking natural riverine flooding.”⁷¹

In addition, to these many failings – including proposing an insufficient amount of mitigation, inappropriate types of mitigation, and over-engineered mitigation – the DEIS also fails to comply with the requirement that mitigation lands for Corps civil works projects must be purchased before any construction begins.⁷² The DEIS explicitly states that mitigation “would progress concurrent with construction of flood control features” including the purchase of mitigation lands.⁷³ However, mitigation lands must be acquired prior to or concurrently with purchase of lands for Project purposes. Only actual physical construction required for purposes of mitigation may be undertaken “concurrently with the physical construction of such project.”⁷⁴

We also note that the DEIS fails to address any uncertainties associated with the proposed mitigation. As aptly noted by the Department of the Interior:

“The DEIS does not adequately address the uncertainties of the proposed mitigation. Without knowing the specific locations of mitigation tracts, or even general locations, the Corps cannot assure the public that such lands are available or are available in an appropriate mix to provide the functions/compensation needed. Without identifying the true costs associated with land acquisition, restoration, operation, maintenance, and potential remediation; it is not possible to determine if the costs identified are credible or that monitoring/adaptive management of those lands will occur.”

⁷¹ November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers.

⁷² 33 USC § 2283(a) (“mitigation, including acquisition of the lands or interests” needed to carry out mitigation “shall be undertaken or acquired before any construction of the project . . . commences, or . . . shall be undertaken or acquired concurrently with lands and interest in lands for project purposes . . . except that physical construction required for the purposes of mitigation may be undertaken concurrently with the physical construction of such project.”)

⁷³ DEIS at 252, 265-266 (Because the undertaking will be long and complex, and will be coordinated with the Inter-Agency Team, USACE will build flexibility and adaptability into the process to, among other things adjust to changes in the willingness of prospective sellers to convey property to the Government. **Therefore, landowners would be periodically surveyed on their amenability to sell mitigation land.**)(emphasis added).

⁷⁴ 33 USC § 2283(a).

“It has been shown that wetland compensation has historically underperformed (Moreno-Mateos et al., 2012) and the Adaptive Management Program does not include details regarding actions that will be taken to rectify mitigation measures that do not work.”⁷⁵

D. The Mitigation “Plan” is Insufficient as a Matter of Law

In addition to meeting the mitigation requirements discussed above, the Corps must also comply with the mitigation plan requirements established by the Water Resources Development Acts and the mitigation plan requirements of the Clean Water Act, including those established in 33 C.F.R. Part 332. The mitigation plan in the DEIS fails utterly to comply with these statutory and regulatory requirements.

Water Resources Development Act Mitigation Plan Requirements

As a matter of law, the DEIS must include a “specific plan to mitigate fish and wildlife losses created” by the Project that must include the following information⁷⁶:

1. The type, amount, and characteristics of the habitat being restored, a description of the physical actions to be taken to carry out the restoration, and the functions and values that will be achieved;
2. The ecological success criteria, based on replacement of lost functions and values, that will be evaluated and used to determine mitigation success;
3. A description of the lands and interest in lands to be acquired for mitigation, and the basis for determining that those lands will be available;
4. A mitigation monitoring plan that includes the cost and duration of monitoring, and identifies the entities responsible for monitoring if it is practicable to do so (if the responsible entity is not identified in the monitoring plan it must be identified in the project partnership agreement that is required for all Corps projects). Corps mitigation must be monitored until the monitoring demonstrates that the ecological success criteria established in the mitigation plan have been met; and
5. A contingency plan for taking corrective action in cases where monitoring shows that mitigation is not achieving ecological success as defined in the plan.⁷⁷

Clean Water Act Section 404 Mitigation Plan Requirements

Pursuant to the Clean Water Act regulatory requirements of 33 C.F.R. Part 332, Corps civil works mitigation plans must also provide a level of detail “commensurate with the scale and scope of the impacts”⁷⁸ and include the following information:

1. “A description of the resource type(s) and amount(s) that will be provided, the method of ecoregion, physiographic province, or other geographic area of interest.”⁷⁹
2. “A description of the factors considered during the site selection process. This should include consideration of watershed needs, onsite alternatives where applicable, and the practicability of accomplishing ecologically self-sustaining aquatic resource restoration,

⁷⁵ November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers.

⁷⁶ 33 U.S.C. § 2283(d).

⁷⁷ 33 U.S.C. § 2283(d)(3).

⁷⁸ 33 C.F.R. 332.4(c).

⁷⁹ 33 C.F.R. § 332.4(c)(2).

establishment, enhancement, and/or preservation at the compensatory mitigation project site.”⁸⁰

3. “A description of the legal arrangements and instrument, including site ownership, that will be used to ensure the long-term protection of the compensatory mitigation project site.”⁸¹
4. “A description of the ecological characteristics of the proposed compensatory mitigation project site This may include descriptions of historic and existing plant communities, historic and existing hydrology, soil conditions, a map showing the locations of the impact and mitigation site(s) or the geographic coordinates for those site(s), and other site characteristics appropriate to the type of resource proposed as compensation. The baseline information should also include a delineation of waters of the United States on the proposed compensatory mitigation project site.”⁸²
5. “A description of the number of credits to be provided, including a brief explanation of the rationale for this determination,” including “an explanation of how the compensatory mitigation project will provide the required compensation for unavoidable impacts to aquatic resources resulting from the permitted activity.”⁸³
6. “Detailed written specifications and work descriptions for the compensatory mitigation project, including, but not limited to, the geographic boundaries of the project; construction methods, timing, and sequence; source(s) of water, including connections to existing waters and uplands; methods for establishing the desired plant community; plans to control invasive plant species; the proposed grading plan, including elevations and slopes of the substrate; soil management; and erosion control measures.”⁸⁴
7. “A description and schedule of maintenance requirements to ensure the continued viability of the resource once initial construction is completed.”⁸⁵
8. “Ecologically-based standards that will be used to determine whether the compensatory mitigation project is achieving its objectives.”⁸⁶
9. “A description of parameters to be monitored in order to determine if the compensatory mitigation project is on track to meet performance standards and if adaptive management is needed. A schedule for monitoring and reporting on monitoring results to the district engineer must be included.”⁸⁷ The mitigation plan must provide for a monitoring period that is sufficient to demonstrate that the compensatory mitigation project has met performance standards, but not less than five years. A longer monitoring period must be required for aquatic resources with slow development rates (e.g., forested wetlands, bogs).⁸⁸
10. “A description of how the compensatory mitigation project will be managed after performance standards have been achieved to ensure the long-term sustainability of the resource, including long-term financing mechanisms and the party responsible for long-term management.”⁸⁹

⁸⁰ 33 C.F.R. § 332.4(c)(3).

⁸¹ 33 C.F.R. § 332.4(c)(4).

⁸² 33 C.F.R. § 332.4(c)(5).

⁸³ 33 C.F.R. § 332.4(c)(6).

⁸⁴ 33 C.F.R. § 332.4(c)(7).

⁸⁵ 33 C.F.R. § 332.4(c)(8).

⁸⁶ 33 C.F.R. § 332.4(c)(9).

⁸⁷ 33 C.F.R. § 332.4(c)(10).

⁸⁸ 33 C.F.R. § 332.6.

⁸⁹ 33 C.F.R. § 332.4(c)(11).

11. "A management strategy to address unforeseen changes in site conditions or other components of the compensatory mitigation project, including the party or parties responsible for implementing adaptive management measures. The adaptive management plan will guide decisions for revising compensatory mitigation plans and implementing measures to address both foreseeable and unforeseen circumstances that adversely affect compensatory mitigation success."⁹⁰
12. "A description of financial assurances that will be provided and how they are sufficient to ensure a high level of confidence that the compensatory mitigation project will be successfully completed, in accordance with its performance standards."⁹¹
13. The mitigation plan must provide for a monitoring period that is sufficient to demonstrate that the compensatory mitigation project has met performance standards, but not less than five years. A longer monitoring period must be required for aquatic resources with slow development rates (e.g., forested wetlands, bogs).⁹²
14. The compensatory mitigation requirements must be clearly stated and include special conditions that "must be enforceable." The special conditions must: "(i) Identify the party responsible for providing the compensatory mitigation; (ii) Incorporate, by reference, the final mitigation plan approved by the district engineer; (iii) State the objectives, performance standards, and monitoring required for the compensatory mitigation project, unless they are provided in the approved final mitigation plan; and (iv) Describe any required financial assurances or long-term management provisions for the compensatory mitigation project, unless they are specified in the approved final mitigation plan...."⁹³ "The special conditions must clearly indicate the party or parties responsible for the implementation, performance, and longterm management of the compensatory mitigation project."⁹⁴
15. "The real estate instrument, management plan, or other mechanism providing long-term protection of the compensatory mitigation site must, to the extent appropriate and practicable, prohibit incompatible uses (e.g., clear cutting or mineral extraction) that might otherwise jeopardize the objectives of the compensatory mitigation project."⁹⁵

A key element of a legally adequate mitigation plan is the inclusion of ecological performance standards for assessing whether the mitigation is achieving its objectives:

"Performance standards should relate to the objectives of the compensatory mitigation project, so that the project can be objectively evaluated to determine if it is developing into the desired resource type, providing the expected functions, and attaining any other applicable metrics (e.g., acres)."⁹⁶

"Performance standards must be based on attributes that are objective and verifiable. Ecological performance standards must be based on the best available science that can be measured or assessed in a practicable manner. Performance standards may be based on

⁹⁰ 33 C.F.R. § 332.4(c)(12).

⁹¹ 33 C.F.R. § 332.4(c)(13).

⁹² 33 C.F.R. § 332.6.

⁹³ 33 C.F.R. § 332.3(k).

⁹⁴ 33 C.F.R. § 332.3(l).

⁹⁵ 33 C.F.R. § 332.7(a).

⁹⁶ 33 C.F.R. § 332.5(a).

variables or measures of functional capacity described in functional assessment methodologies, measurements of hydrology or other aquatic resource characteristics, and/or comparisons to reference aquatic resources of similar type and landscape position. The use of reference aquatic resources to establish performance standards will help ensure that those performance standards are reasonably achievable, by reflecting the range of variability exhibited by the regional class of aquatic resources as a result of natural processes and anthropogenic disturbances. Performance standards based on measurements of hydrology should take into consideration the hydrologic variability exhibited by reference aquatic resources, especially wetlands. Where practicable, performance standards should take into account the expected stages of the aquatic resource development process, in order to allow early identification of potential problems and appropriate adaptive management.”⁹⁷

The mitigation plan in the DEIS does not comply with these clear and specific requirements. For example, among its many other mitigation plan failings:

- The DEIS fails to provide any specific mitigation plan. Instead it, at best, includes conceptual explanations of plans that will be developed in the future. The DEIS explicitly states that specific mitigation plans will not be developed until mitigation lands are acquired.⁹⁸
- The DEIS fails to describe the type, amount, and characteristics of the habitat being restored and fails to describe the physical actions to be taken to carry out the restoration, and the functions and values that will be achieved.
- The DEIS fails to identify or describe any specific mitigation lands, and fails to provide any meaningful explanation as to the basis for determining that mitigation lands will be available. Indeed, the DEIS specifically states that landowners will not be queried about their willingness to sell land for mitigation purposes until a final decision is made on the Project.⁹⁹ The Corps’ claims that it is “reasonable to assume”¹⁰⁰ that mitigation lands can be acquired from willing sellers is wholly unsupported by evidence and is directly contradicted in the DEIS which states that “[measures that take productive agricultural land out of production and reforest it are not supported by local landowners (St. John Levee and Drainage District, personal communication)].”¹⁰¹
- The DEIS fails to identify the ecological success criteria that will be used to determine whether the mitigation is working as promised. Referencing the number of habitat units that will be replaced by the mitigation does not satisfy the requirement to include ecological success criteria and does not meet the definition of the required performance standards in 33 C.F.R. Part 332.
- The DEIS does not include a detailed monitoring plan that includes the cost and duration of monitoring, and it does not identify entities responsible for monitoring.

⁹⁷ 33 C.F.R. § 332.5(b).

⁹⁸ DEIS at 251.

⁹⁹ DEIS at 251.

¹⁰⁰ See *e.g.*, DEIS at 249, 250.

¹⁰¹ DEIS at 49.

- The DEIS does not include a contingency plan for taking corrective action in cases where monitoring shows that mitigation is not achieving ecological success as defined in the plan.
- The DEIS does not include enforceable mitigation conditions and does not include reasonable financial assurances for carrying out the promised mitigation.

The failures to meet the mitigation plan requirements are also addressed in the 2013 Zedler Report.

VI. The Project Is At Odds with Longstanding Federal Policy

The Project is fundamentally at odds with longstanding federal policy and should not be constructed. As discussed throughout these comments, the Project is also prohibited under Section 404 of the Clean Water Act, should be vetoed under Section 404(c) of the Clean Water Act, fails to comply with the National Environmental Policy Act, and ignores the critical ecological and flood protection values of floodplain, wetland, and backwater habitat.

The Project's fundamental components – eliminating the river-floodplain connection and draining wetlands – to promote increased agricultural production are archaic concepts from another era and are in direct conflict with current federal policy. According to the Draft EIS, 75 percent of the alleged benefits from the Project come from agricultural production making it clear that agricultural drainage is in fact the project's primary purpose.

The TSP will eliminate the last natural connection and the related natural functions, between the Mississippi River and its floodplain in the state of Missouri, will destroy tens of thousands of acres of wetlands, and will encourage intensified use of the New Madrid Floodway. By eliminating the natural flood regime, eliminating natural access to backwater habitat, and damaging tens of thousands of acres of wetlands, the Project also significantly undermines the resiliency and sustainability of the region's fish and wildlife in the face of climate change. The adverse impacts of the Project cannot be mitigated.

As a result, the Project violates or works against **at least** the following federal policies and initiatives:

The National Water Resources Planning Policy

"It is the policy of the United States that all water resources projects" should among other things, reflect national priorities and protect the environment by "protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems" and by "seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used."¹⁰² The Project violates this policy as it will do just the opposite.

National Wetlands and Floodplain Policies

A broad array of federal laws and policies promote protection of the nation's remaining wetlands and floodplains and restoration of those resources to reverse historic wetland losses. Such Federal laws include, the Clean Water Act; the 1985 and 1990 Farm Bills; the Emergency Wetlands Protection Act of 1986; the Water Resources Development Acts of 1986, 1992, and 1996; the Agriculture Credit Act of 1987; the Conservation Reserve Program; the Food Security Act of 1992; the Wetlands Reserve Program

¹⁰² 42 USC § 1962–3.

(WRP); and the Federal Agriculture Improvement and Reform Act of 1996. Longstanding Executive Orders also call for the protection of wetlands and floodplains. For example:

- 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."
- The Water Resources Development Act of 1990 establishes a wetlands protection goal for Corps civil works projects. That Act establishes "an interim goal of no overall net loss of the Nation's remaining wetlands base, as defined by acreage and function, and a long-term goal to increase the quality and quantity of the Nation's wetlands, as defined by acreage and function." 33 U.S.C. § 2317(a)(1). That Act further established "environmental protection as one of the primary missions of the Corps of Engineers in planning, designing, constructing, operating, and maintaining water resources projects." Water Resources Development Act of 1990, 33 U.S.C. § 2316(a) (emphasis added).
- Provisions referred to as Swampbuster, sections 1201-1224 of the Food Security Act of 1985, as amended, 16 U.S.C. 3801 et seq., bar participation in a wide variety of important agricultural support programs to farmers who either convert wetlands after 1985 or who plant crops on wetlands that have been converted since 1985. Conversion has been defined by regulations at 7 C.F.R. Sections 12.-12.34, to include the additional drainage of wetlands regardless of whether it completely eliminates all wetland conditions. Under the statute and regulations, farmers are responsible for drainage done with the assistance of drainage districts, and mitigation for wetland drainage may not be done at federal expense. This project will drain thousands of acres of farmed wetlands as set forth in the attached Report of Dr. Joy Zedler. Doing so will cause farmers to be ineligible under Swampbuster for a host of farm payments. The implications of this ineligibility are not addressed in the DEIS at all, and are also ignored because the Corps improperly claims that only approximately 1,000 acres of inundated farmland qualify as farmed wetlands.
- The Wetland Reserve Program (WRP), administered by the USDA Natural Resources Conservation Service, is a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. The program provides technical and financial support to help landowners with wetland restoration efforts and establish long-term conservation and wildlife practices and protection. Lands eligible for WRP include farmed wetlands, prior converted cropland, riparian areas that link protected wetlands and lands that have the potential to become a wetland as a result of flooding. Lands enrolled are placed under a conservation easement and undergo restoration. The USDA will pay 100 percent of the easement value and restoration costs for perpetual easements, and 75 percent of the easement value and restoration costs for 30 year easements.

- The Conservation Reserve Program (CRP), administered by the Farm Services Agency, is a voluntary program for agricultural landowners. CRP provides annual rental payments, cost-share assistance and technical assistance to establish long-term, resource conserving covers on eligible farmland. It is often referred to as the nation's largest voluntary private lands conservation program. Eligible owners or operators may place highly erodible or other environmentally-sensitive land into a 10 to 15 year conservation contract.
- The Conservation Stewardship Program (CSP), administered by the USDA Natural Resources Conservation Service, is a voluntary program which encourages agricultural and forestry producers (including Tribal producers) to address resource concerns by: (1) undertaking additional conservation activities; and (2) improving and maintaining existing conservation systems. CSP provides financial and technical assistance to help land stewards conserve and enhance soil, water, air, and related natural resources on their land. The beneficiaries of the CSP program must refrain from damaging or draining wetlands on their lands.
- In recent years substantial funds have been provided through Supplemental Appropriations bills for the USDA Emergency Watershed Protection Program, with much of this funding being used to purchase floodplain easements to help restore previously drained or degraded wetlands and to restore naturally functioning floodplains. The Secretary of Agriculture is authorized to utilize the purchase of floodplain easements as an emergency restoration measure.¹⁰³

The Project is at odds with Executive Order 11990 (Protection of Wetlands) and Executive Order 11988 (Floodplain Management), and works against the goals and initiatives designed to protect and restore wetlands and floodplains. The Project will add significantly to – not reverse – historic wetland losses.

National Climate Change Policies

The scientific recognition of our changing climate has led to federal policies requiring greater consideration of the effects of climate change on federal infrastructure investment and planning. For example, in 2012, the Department of the Interior adopted policy guidance to address climate change in project planning that include: (1) promoting landscape-scale ecosystem-based management approaches to enhance resilience and sustainability of linked human and natural systems; (2) protecting diversity of habitat communities and species; (3) protecting and restoring core, unfragmented habitat areas and the key habitat linkages among them; and (4) maintaining key ecosystem services.

Most recently, on November 13, 2013 the President issued an Executive Order entitled "Preparing the United States for the Impacts of Climate Change." Among other things, this Executive Order requires federal agencies to "complete an inventory and assessment of proposed and completed changes to their land- and water-related policies, programs, and regulations necessary to make the Nation's watersheds, natural resources, and ecosystems, and the communities and economies that depend on them, more resilient in the face of a changing climate" and in recognition of "the many benefits the Nation's natural

¹⁰³ Section 216, P.L. 81-516, as amended, 16 U.S.C. § 2203 (emphasis added) ("The Secretary of Agriculture is authorized to undertake emergency measures, **including the purchase of floodplain easements**, for runoff retardation and soil erosion prevention, in cooperation with landowners and land users, as the Secretary deems necessary to safeguard lives and property from floods, drought, and the products of erosion on any watershed whenever fire, flood, or any other natural occurrence is causing or has caused a sudden impairment of that watershed.")

infrastructure provides” directs agencies to focus on program and policy adjustments that promote the dual goals of greater climate resilience and carbon sequestration where possible.

The Project works against these critical policies and goals by, among other things, significantly undermining the resiliency and sustainability of fish and wildlife populations by eliminating the natural flood regime that sustains those populations and the wetlands that they rely on.

Association of State Floodplain Managers Levee Policies

In 2007, the Association of State Floodplain Managers issued a statement on Levee Policy which included the following recommendations, both of which would be violated by construction of the New Madrid levee:

- “Levees should be used as a structure of last resort and only after other measures, especially nonstructural ones, have been fully considered. Levees should not be used as a means to facilitate the development of currently undeveloped floodprone lands.”¹⁰⁴
- “Levees should not be constructed in floodways and, to the maximum extent possible, when constructed or reconstructed levees should be set back from rivers to allow the river to function more naturally and to provide for the protection or restoration of riparian and wetland resources between the river bank and the levee.”¹⁰⁵

Restoration Policies and Initiatives

Restoring backwater habitat is a primary goal of the Corps’ restoration efforts under the Environmental Management Program and the Upper Mississippi River System Navigation & Ecosystem Sustainability Program. The Project works against these key restoration efforts because it will destroy vital backwater habitat.

VII. The DEIS Is Fundamentally Flawed

As discussed throughout these comments, the DEIS is fundamentally flawed and does not comply with the requirements of the National Environmental Policy Act. The DEIS relies on outdated model and data and lacks scientific integrity; fails to demonstrate project need; fails to properly consider reasonable, less damaging alternatives, and fails to examine the full suite of adverse impacts from the Project.

A. The DEIS Relies on Outdated Models, Lacks Scientific Integrity, and Fails to Address Many Significant Issues Raised by the External Independent Peer Review Panel

The DEIS must be based on “high quality” science and information as “[a]ccurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA.”¹⁰⁶ The Corps must also “insure professional integrity, including scientific integrity, of the discussions and analysis in

¹⁰⁴ Levees: The Double-edged Sword, Adopted by the ASFPM Board April 17, 2007 at 6.

¹⁰⁵ *Id.*

¹⁰⁶ 40 C.F.R. § 1500.1(b).

environmental impact statements."¹⁰⁷ This requires the Corps to candidly disclose the risks of its proposed action and to respond to adverse opinions held by respected scientists.¹⁰⁸ It also prohibits the Corps from relying "on conclusory statements unsupported by data, authorities, or explanatory information."¹⁰⁹ Importantly, 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."¹¹⁰

The DEIS and the Corps' decision to select the TSP do not satisfy these fundamental NEPA requirements. To the contrary, despite studying this project for decades – and highlighting the need for utilizing modern and scientifically sound models and data in the DEIS¹¹¹ – the Corps relies on outdated models and data and fails to include information that is critical for making an accurate assessment of project need and benefits.

For example, the DEIS contains no data on actual flood damages in the Project area. This information is critical for determining whether this project is actually needed, and whether the project will produce a positive return on the taxpayer's investment. The DEIS also fails to identify the elevations or number of farms in the Project area to more accurately determine potential benefits, despite the fact that the Corps has claimed that 75 percent of the project benefits come from agriculture. See Section VII.B. of these comments for additional examples of critical information that is missing from the DEIS.

A number of the models used by the Corps are outdated, unexplained, unverified, or inappropriate for the purposes for which they were used. For example, as noted below, the Department of the Interior and FWS have repeatedly told the Corps that the HGM model it has used is inappropriate for evaluating the impacts of this Project. As discussed in more detail in Section VII.D. of these comments, the economic model used by the Corps has not been explained or verified. As discussed in more detail in Section VII.L. of these comments, the Corps used a 1950s era physical model to evaluate the effect on flood heights of constructing the New Madrid levee (closing the 1,500 foot gap). The Corps ran that model in 1989 or 1990 and has not updated it since then.¹¹²

The DEIS also ignores opposing views and recommendations made by respected scientists, including resource agency experts and independent scientists. The DEIS also draws conclusions that are fundamentally contradicted by modern science and/or are completely unsupported by any evidence. The following are just a few of the many examples of opposing views and recommendations made by respected scientists that have not been addressed in the DEIS:

¹⁰⁷ 40 C.F.R. § 1502.24 ("Agencies shall insure professional integrity, including scientific integrity, of the discussions and analysis in environmental impact statements"); *Earth Island Inst. v. U.S. Forest Service*, 442 F.3d 1147, 1159-60 (9th Cir. 2006) (quoting 40 CFR §1502.24).

¹⁰⁸ *Seattle Audubon Soc'y v. Mosely*, 798 F.Supp. 1473, 1482 (W.D. Wash. 1992) (citing *Friends of the Earth v. Hall*, 693 F.Supp. 904, 934, 937 (W.D.Wash. 1988)).

¹⁰⁹ *Id.*

¹¹⁰ 40 C.F.R. § 1502.22.

¹¹¹ See DEIS at v (Figure S.1) and 16.

¹¹² DEIS Appendix C at C-18; Mississippi Basin Model Letter Report 89-1, Birds Point-New Madrid Floodway Reconnaissance Study, dated July 27, 1990 ("The MBM is of the fixed-bed type, reproducing a large portion of the Mississippi River and its major tributary system to a horizontal scale of 1:2000 and a vertical scale of 1:100. General features of the model, including appurtenances, instrumentation, and operating procedures, are discussed in detail in MBM Report 1-4, DESCRIPTION OF THE MISSISSIPPI BASIN MODEL, dated 18 July 1951.")

- The Department of the Interior has advised the Corps that “[a]ltering the hydrologic regime of the floodway . . . is at odds with contemporary understanding of wetland and floodplain science and agency mitigation guidance. This science emphasizes the critical importance of natural hydrology, spatial extent, and landscape position. The science recognizes the importance to habitat values of subtle features of hydrology, including depth, velocity, and timing of flooding and the relationship of one habitat to another.”¹¹³
- The Independent External Peer Review Panel has advised the Corps that **“closing the last connection would have a significant cumulative impact on the flood-dependent system.** While it is not required that a project compensate for historical impacts, it is incumbent on the project not to contribute the incremental impact that may cause the project to exceed this overall threshold.”¹¹⁴
- The Fish and Wildlife Service has “provided extensive comments and data (i.e., National Wetlands Inventory; Appendix Q, draft Fish and Wildlife Coordination Act) indicating a substantially larger area of functional wetlands would be affected by the proposed project. The Corps was also informed that the species-specific assessment models used to evaluate wetland impacts do not adequately quantify the importance or the effects to the wetlands evaluated.”¹¹⁵
- The Department of the Interior “has consistently discouraged the Corps from using the Hydrogeomorphic Method (HGM) to evaluate wetlands and that the analysis did not include all of the potentially affected wetlands. . . . The Missouri Interagency Review Team (IRT) has considered a number of wetlands assessment tools to use for wetland mitigation determinations and does not use HGM. The Missouri IRT has developed an alternative assessment methodology to best reflect wetlands impacts and benefits from various management actions. HGM is cumbersome and requires a great deal of data to populate the many variables and functions in the models. In addition, users must make many assumptions to conduct a robust, thorough analysis. Some of the models/functions are insensitive to hydrologic changes and other important factors not easily measured in the field (e.g., wildlife interactions, minimum acreage requirements for species, wildlife and fish access to an area, rarity of biotic communities). Thus HGM has significant limitations as an assessment tool for this and other projects.”¹¹⁶
- The Department of the Interior and FWS have raised significant objections to the Corps’ conclusion that “the flood pulse is not a driving factor for the ecology of rivers that have been broadly manipulation. This assertion is significant, is at odds with the information presented in the FWS’s Draft FWCA report (including numerous-peer reviewed articles) and should be well-supported with citations from scientific literature. . . . The scientific literature is rich with examples from around the globe of restored and managed functioning floodplain ecosystems in large rivers that are highly modified to eliminate channel meander and regulated for human use, exactly like the Mississippi River. . . . Despite flood control efforts and water management along

¹¹³ August 26, 2011 Letter from Acting Assistant Secretary for Fish Wildlife and Parks to Assistant Secretary of the Army for Civil Works.

¹¹⁴ DEIS Volume 3 Part 4, Phase III IEPR Final Comment Response Record at 61 (emphasis added).

¹¹⁵ November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers.

¹¹⁶ *Id.*

the Mississippi River, it is clear that flows are indeed dynamic (e.g., recent extreme floods in 2010 and 2011, and extreme drought in 2012). Therefore, ecologically based theory such as the Flood Pulse Concept (FPC) and Low Flow Recruitment Hypothesis (LFRH; see Humphries et al. 1999), is directly relevant to our understanding of the importance of the remaining dynamic hydrology of the river that shapes ecosystem function. Thus, Ward and Stanford (1995) recommend the focus of restoration efforts on reestablishing dynamic connectivity between the channel and floodplain.”¹¹⁷

The DEIS also fails to adequately address many significant concerns raised by the Independent External Peer Review panel (IEPR Panel). For example:

In **Comment 4** of the Phase III IEPR Final Comment Response Record¹¹⁸, the IEPR Panel pointed out that the assumptions associated with food availability for waterfowl are not appropriate and provide unreliable estimates of biomass for waterfowl. A primary reason for the IEPR Panel’s comment was the Corps’ assertion that because herbaceous wetlands provide a greater amount of food availability than cypress-tupelo or riverfront forest (black willow/cottonwood), compensatory mitigation calculations are under valuing the benefit to waterfowl and, therefore, mitigation may be over compensating for waterfowl impacts. The IEPR Panel made clear that it disagreed with the Corps’ assertion because the production of these areas will be completely dependent on the hydrology, which controls what species of vegetation are produced, and which is unknown. Therefore, according to the IEPR Panel, these areas may very well produce more food than the aforementioned habitats, but may actually produce little to no food for waterfowl.

In the DEIS, the Corps continues to assert that the compensatory mitigation features would result in a net gain to waterfowl and, therefore, there will be an increase to waterfowl habitat as a result of the project.¹¹⁹

In **Comment 5**, the IEPR Panel noted that the wetland cover (acreage) and quality are poorly documented. In the February 2011 Appendix E, Part 1 Report, USEPA identified 149,802 acres of wetlands in the St. Johns/New Madrid Bayou/Floodway. The IEPR Panel agreed that it was appropriate for USEPA to include farmed wetlands in their wetland survey. The IEPR Panel stated that without a firm resolution of the total area of wetlands affected by this project, few of the wetland impact or mitigation estimates are meaningful. The IEPR Panel called on the Corps to provide additional detail on the wetland estimating methodology used by both agencies. The IEPR Panel strongly believed that “non-jurisdictional wetlands such as some farmed wetlands and most bottomland hardwood forests provide many ecosystem functions and habitats that should be included in an EIS, regardless of their legal standing.”

In its response the Corps promised to clarify in the DEIS its position that “wetlands are over-compensated for in either the NRCS estimate or the EPA estimate.” Further, the Corps represented that “Both the EPA and NRCS methodology will be included in an appendix with the appropriate level of detail so one could duplicate the effort.”

¹¹⁷ *Id.* at Specific Comments page 5.

¹¹⁸ Each of the Comments referred to in this Section can be found at DEIS Volume 3, Part 4 Phase III IEPR Final Comment Response Record.

¹¹⁹ See DEIS at 234.

In the DEIS, however, the Corps has swept the issue under the rug. EPA's methodology is absent from the DEIS. There is no detailed clarification of EPA's position.

In **Comment 6**, the IEPR Panel stated that "[t]he HGM methodology lacks the appropriate detail to validate the analysis results." If the results are uncertain, then the validity of the calculations for mitigation will also be uncertain. Because the HGM methodology is based on "professional educated guesses," the IEPR Panel requested the Corps use an alternative method of analysis to complement the HGM model to describe the effects of each alternative on the ecosystem services of wetlands. The Corps responded by not adopting the IEPR Panel's recommendation. It asserted that it already had complemented the HGM method with other methods (e.g., fish, waterfowl, shorebirds, and water quality) and that these would be sufficient to "describe the effects of the alternatives on a suite of environmental services." In reply, the IEPR Panel reiterated the need for an additional method that would determine ranges and probabilities of FCI values. The IEPR Panel stated "[o]therwise, the HGM technique, with all its exquisite details, gives the impression that it is analytically rigorous while it does, in effect, have a great deal of uncertainty associated with it."

The Corps has not complemented the HGM method with any other methods. Therefore, a significant amount of uncertainty remains as to the sufficiency of the mitigation calculations.

In **Comment 11**, the IEPR Panel stated that the "adaptive management plan lacks the details necessary to ensure that environmental resources affected by the project are appropriately mitigated." According to the IEPR Panel, "[t]he adaptive management approach requires both a monitoring and response phase." The IEPR Panel noted that there "is no indication as to what type of modification would occur in the mitigation plan (e.g., increase in mitigation acreage) if the mitigation actions do not meet objectives."

The Corps responded by stating that the "Draft EIS will be expanded to include more details regarding short term monitoring." The Corps promised that short term monitoring would include parameters such as hydraulics and hydrology and percent survivorship of newly planted vegetation and promised that "Section 6 of the Draft EIS will be expanded to include more details." The Corps further promised that "Waterfowl – Section 6.4.3 will be expanded to include methods that would be utilized to assess available waterfowl food." According to the Corps, "Details regarding costs would also be provided."

The Corps, however, did not include the necessary information in the DEIS. Instead, relevant sections of the DEIS continue to be ambiguous and to lack specificity. For example, the DEIS states merely that, "Tract-specific objectives will be developed for each tract-specific mitigation plan."¹²⁰ Also, for example, Table 5.7 (concerning "preliminary compensatory mitigation monitoring parameters") lacks the promised detail. Parameters set out in the table, for example, list only in general terms such as "Success of Planted Vegetation" and "Hydrology functioning as designed (duration, depth, timing)."¹²¹

Further, under the section dealing with "Tract-Specific Remedial Actions," for example, the Corps states only in general terms that, "it may be determined to change the overall mitigation feature to a different feature. . . Therefore, a new mitigation plan would be developed for the tract. . . . In the event of

¹²⁰ DEIS at 265.

¹²¹ DEIS at 271.

significant deficiencies on multiple mitigation tracts, the overall operation of the project may be modified through overall project adaptive management.”¹²²

The lack of detail carries on, for example, to Section 7.3, concerning “Adaptive management Thresholds,” where the DEIS states only that: “To reach these goals, adaptive management thresholds would be set, at which additional or other mitigation measures would be taken (i.e., above or beyond those described in Section 5). . . . The thresholds for instituting adaptive management actions would be based on the point estimates necessary to compensate for project impacts with the inclusion of variance estimates determined in Section 6 (Figure 7.1).” At best, these statements describe project adaptive management generally, but lack the necessary detail. The same holds true, for example with section 7.4.2 titled “Waterfowl” where the DEIS states only that, “A measure that may aid waterfowl mitigation would be to adaptively manage flood waters for their benefit from December into February and possibly early March, rather than curtailing this activity by January 31.”¹²³

Further, concerning the Corps’ promise to provide “methods that would be utilized to assess available waterfowl food,” the DEIS says only that “How much food would be available to waterfowl would be projected using standard methods to compare the chosen mitigation sites to the estimated annual production of major food sources” and that “The assessment would occur at least once prior to each adaptive management report and cover each type of waterfowl habitat listed above. Waterfowl mitigation measures would be assessed until ecological success criteria are achieved.” Section 7.2.4, p. 297. These are not detailed methods but only general statements. The DEIS also fails to provide the promised “details regarding costs.”

Many additional problems with the Corps’ proposed mitigation are discussed in detail in Sections V. and VII. of these comments.

In **Comment 12**, the IEPR Panel pointed out that the adaptive management plan does not provide specific details on the source(s) of funding needed to implement the plan. According to the IEPR Panel, without a source of funding, crucial adaptive management activities would likely be halted, jeopardizing the success of the project. The IEPR Panel noted that the source of funding is a critical aspect of the adaptive management plan that needs to be identified to ensure that the project goals are achieved.

The Corps responded that “specific costs and details associated with adaptive management would be presented in the Draft EIS.” However, this information is not included. For example, instead of providing “specific costs” the DEIS states, for example, that “Maintenance of mitigation sites would be subject to specific authorization for each specific portion of the project.”¹²⁴ Further, while the DEIS states that “[w]ith the exception of routine maintenance provided by the project sponsor, the Federal government would be responsible for maintaining the structure necessary to restore hydrology to Big Oak Tree State Park,” detailed costs are not provided.¹²⁵

The DEIS also does not provide details associated with adaptive management, and fails even to identify the agency that would be responsible for long-term management:

¹²² DEIS at 274-275.

¹²³ DEIS at 303.

¹²⁴ DEIS at 267-229.

¹²⁵ DEIS at 269.

“Under current authorities and policies, mitigation lands acquired in fee for the New Madrid Floodway portion of the project, specifically lands acquired by the Federal government **could be transferred** over to the FWS once mitigation acquisition is completed and determined to meet ecological success criteria. The FWS **could then** transfer the lands over to a state agency/third-party for long-term management. Lands acquired by the St. John Levee and Drainage District **could be transferred** to a state agency or third party if determined appropriate. **If the FWS determines not to accept** the lands, USACE would maintain long-term management. USACE **would likely license** long term management to a suitable third party, such as MDC, MDNR, or other interested partner. The interagency team would be consulted with prior to turning over any mitigation lands. **It is the intent of USACE to turn over mitigation lands to a suitable third party.**”¹²⁶

In **Comment 13**, the IEPR Panel pointed out that the fisheries adaptive management plan requires additional fish passage studies and lacks the detail needed to establish monitoring frequency. The IEPR Panel noted that specific monitoring “details for connectivity, access, hydrograph, and Habitat Suitability Index (HSI) values” were not provided in the DEIS and are needed to evaluate mitigation as part of the adaptive management process.

The DEIS fails to provide the needed detail. The EIS simply states that, “Adult fish usage would be monitored”¹²⁷ Further, regarding “specific monitoring details for connectivity, access, hydrograph, and Habitat Suitability Index (HSI) values,” the DEIS parrots these words, but fails to provide the necessary detail. According to the DEIS, “The assessment would include, but would not be limited to, documenting fish usage by spawning adults (richness and diversity), fish usage by rearing larvae and young of the year (richness and diversity), connectivity, fish access, habitat transition periods, and the hydrograph (i.e., rising and falling stages).”¹²⁸

In **Comment 19**, the IEPR Panel noted that the methods and model used to assess the impacts on fish and to estimate the compensatory mitigation are not clearly described. The IEPR Panel made several recommendations.

First, the IEPR Panel asked the Corps to reference and define the timing of the connectivity in Section 4.8.5.2. Further, the IEPR Panel said that tables 4.47, 4.48, 4.49, and 4.50 should include percentage of connectivity loss for alternatives. The Corps ignored the requests. The DEIS does not define the timing of connectivity and fails to include the percentage of connectivity loss in the tables.

Second, the IEPR Panel asked the Corps to provide clarification of reproductive success that focuses on population level maintenance that can be achieved. For its response, the Corps promised that a “discussion in the Draft EIS will be provided on population-level success.” However, the discussion consists of statements that fall short of discussing “reproductive success which focuses on achievable population level maintenance.” For example, the DEIS notes that “few studies have been conducted on fish access through culverts, and those studies that have shown impacts are related to small road crossing culverts or located in geographically disparate regions.”¹²⁹ The DEIS states that “monitoring fish passage after the project is completed would provide additional information to possibly refine access

¹²⁶ DEIS at 275 (emphasis added).

¹²⁷ DEIS at 298.

¹²⁸ DEIS at 298.

¹²⁹ DEIS at 157.

coefficients.”¹³⁰ The DEIS later states “there is uncertainty regarding fish passage.”¹³¹ These statements make clear that the Corps has not implemented culverts of the type it proposes here and has no predictive studies showing they will work. This is not a discussion of “population maintenance that can be achieved.”

Third, the IEPR Panel asked the Corps to provide clarification of why access coefficients were not calculated for each spawning/rearing season. The Corps responds in the DEIS by stating that “it **can be argued** that those fish unable or unwilling to move through the culverts can spawn elsewhere and the fish access reduction coefficient is unnecessary.”¹³² This unsupported assertion falls short of the clarification requested by the IEPR Panel.

Fourth, the IEPR Panel stated that for comparative purposes, clarity would be improved by presenting reduced AAHUs as both lost AAHUs and as a percentage for each habitat type and total pooled habitats in Tables 4.34 to 4.39. The Corps responded by promising that “the recommendations regarding clarity will be adopted and the Draft EIS will be revised.” However, the DEIS does not present reduced and lost AAHUs as percentages. It would present a more compelling case **against** the project if percentages were shown in Tables 4.52 and 4.53, in addition to number of acres lost.

Finally, the IEPR Panel recommended that mitigation in batture land and floodplain lakes should be limited to no more than 27% of AAHUs based on the fish access coefficient (0.73). The Corps rejected this recommendation.

In **Comment 20**, the IEPR Panel noted that the description of fisheries resources is inconsistent and is not adequately explained. The IEPR Panel asked the Corps to revise the DEIS to eliminate conflicting descriptions and conclusions, delete a particular statement of an environmental advocacy group which the Corps was using to support the claim that the project will have an insignificant impact to fish spawning and rearing habitat, and remove the language suggesting that the project area has no value or significant habitat for fish resources. The IEPR Panel pointed out that it was “unaware of any scientific publications that state the Mississippi River ecosystem is destroyed and has no remaining value either economically or biologically.” The IEPR Panel also asked the Corps to remove Section 4.17, Loss of Connectivity in the Cumulative Impacts section, from the DEIS because the panel believed that the language had “nothing to do with cumulative impacts and qualitatively dismisses the fish resources that were quantified in the DEIS.”

Although the Corps responded to the IEPR Panel by committing to revise the DEIS (though the Corps declined to remove the connectivity section from the cumulative impacts section), the Corps did not make the recommended changes.¹³³

In **Comment 22**, the IEPR Panel pointed out that the positive ecological effects of the flood pulse on the landscape are not considered and the flood pulse is applied inaccurately in a social impact context. The IEPR Panel elaborated that the historical accounts of human suffering due to flood pulses should not be tied to Junk’s concept of flood pulsing. The IEPR Panel advised the Corps that this is an artificial connection between an ecological concept and social effects of flooding and as a result language linking

¹³⁰ DEIS at 160.

¹³¹ DEIS at 293.

¹³² DEIS at 160 (emphasis added).

¹³³ See DEIS Section 4.20 at 255.

the two should be removed from the document. More importantly, according to the IEPR Panel, the economic benefits of flood pulsing are not described in the DEIS or in the benefit-cost section. Flood pulses are natural subsidies to ecosystems such as bottomland hardwood forests and backwater wetlands. Floods cause an increase in nutrient availability to wetlands in these settings, as well as increased nutrient cycling due to water level fluctuations.

Although the Corps “concurred” with the IEPR Panel’s comment, the DEIS still ties Junk’s study to human suffering, again making what the IEPR Panel called, “an artificial connection between an ecological concept and social effects of flooding; the link should be removed from the document.” The Corps cited Junk in Section 3.5 (DEIS at 62) and followed that section with six pages of detailed historical suffering, effectively making the connection to Junk. Furthermore, the Corps nowhere mentioned that flooding made fields rich and able to support cultivation,¹³⁴ as the IEPR Panel stated: “Floods cause an increase in nutrient availability to wetlands in these settings, as well as increased nutrient cycling due to water level fluctuations.

In **Comment 23**, the IEPR Panel made clear that the cumulative impacts analysis does not consider the value of ecosystem services that have diminished over time. According to the IEPR Panel, the “DEIS assigns little value to the ecosystem services . . . provided by floodplain connection to the Mississippi River. The . . . ecological value of the remaining connection to the Mississippi River is high. . . . [and] closing the last connection would have a significant cumulative impact on the flood-dependent system. . . . Throughout the DEIS, ecosystem services are not considered or are undervalued, while economic benefits may be inflated and based on previous socioeconomic data.”

While the DEIS includes an extremely limited evaluation of just two of many ecosystem services (carbon sequestration and nutrient cycle), the conclusion ignores the lost ecosystem services from the Project and instead concludes, without justification or explanation, that the proposed mitigation would increase the ecosystem services of the area. At the most basic level, this conclusion is fundamentally incorrect. The purpose of mitigation is to replace the resources lost to the project, so at the most basic level mitigation would simply replace the ecosystem services lost to the project (assuming that mitigation was successful; as discussed in these comments many experts have concluded that the adverse impacts of the Project cannot be mitigated).

In **Comment 26**, the IEPR Panel pointed out that the description of shorebird resources includes inconsistencies and inaccuracies. Specifically, the DEIS states that, historically, the project area did not provide any suitable shorebird habitat. The IEPR Panel believes it is likely, based on general geomorphologic principles, that river scour areas and other similar river features, as well as margins of open wetland areas, provided sparsely vegetated areas suitable for shorebirds before landscape conversion. The IEPR Panel stated that the “historical value of the project area for shorebirds should be accurately described so that the resource is accurately represented throughout the DEIS.”

While the Corps concurred with the IEPR Panel’s comment, it did not revise the DEIS. The DEIS continues to state that “Historically, the project area did not provide any suitable shorebird habitat.”¹³⁵

¹³⁴ See DEIS at 62-63.

¹³⁵ DEIS at 221, 224.

B. The DEIS Fails to Demonstrate Project Need

The DEIS fails to demonstrate that the Project is needed or in the national interest. The Corps' conclusion that it "is obliged by law to accomplish the will of Congress for flood risk management in Southeast Missouri"¹³⁶ does not demonstrate Project need.

Moreover, this conclusion ignores law, policy, and reality on the ground. First, this conclusion ignores the fundamental purpose of the National Environmental Policy Act, which is to examine the full suite of impacts and determine whether less damaging alternatives are available before deciding **whether or how to proceed**. Second, this conclusion ignores critical elements of the Corps' planning process – notably, the ability of the agency to conduct a general reevaluation project to determine whether a project remains appropriate for construction. Finally, this conclusion ignores the realities of the Corps' project backlog and funding limitations. The Corps currently has an estimated backlog of more than 1,000 authorized activities that will take an estimated \$60 billion to construct.¹³⁷ The Water Resources Development Act of 2013 which is likely to be enacted into law this year or early next year will add to this backlog. For more than a quarter century, new project authorizations have vastly outpaced appropriations,¹³⁸ and it is highly unlikely that the Corps will ever being able to build all the projects that are currently authorized for construction.

The DEIS concludes that 75 percent of the alleged benefits from the Project come from agricultural production making it clear that the project's primary purpose is agricultural drainage. The DEIS also claims another 22 percent of alleged project benefits from avoiding the need to raise Interstate 55 (I-55) to avoid flood damage.¹³⁹ Section VII.D. of these comments provides a detailed discussion of the many problems with the economic analysis in the DEIS.

As a fundamental matter, eliminating the river-floodplain connection and draining wetlands to promote increased agricultural production are archaic concepts from another era and are in direct conflict with current federal policy. As a result, there could be few, if any, circumstances where such a project could be considered to be in the national interest.

In addition, the DEIS lacks the most basic information needed to determine whether there is even a need for a flood damage reduction project in the Project area. For example, as discussed throughout these comments, the DEIS contains no data on actual flood damages in the Project area. The Corps contends that "[r]eliable estimates of crop damage due to flooding do not exist."¹⁴⁰ However, because

¹³⁶ DEIS at 4.

¹³⁷ Nicole T. Carter and Charles V. Stern, "Army Corps of Engineers Water Resource Projects: Authorization and Appropriations," Congressional Research Service R41243, March 22, 2013.

¹³⁸ Nicole T. Carter and Charles V. Stern, "Army Corps Fiscal Challenges: Frequently Asked Questions," Congressional Research Service R41961, August, 18 2011.

¹³⁹ The Corps has concluded that approximately 38 percent of Project benefits come from crop damage reduction, approximately 14 percent of Project benefits come from agricultural non-crop benefits, approximately 23 percent of Project benefits come from agricultural intensification, and approximately 24 percent of Project benefits come from reduced flood damages to roads and streets. Donald C. Sweeney II, Ph.D., A Review of the Economic Analysis Presented in the St. Johns Bayou and New Madrid Floodway July 2013 Draft Environmental Impact Statement, prepared for the National Wildlife Federation and the Great Rivers Environmental law Center (November 8, 2013). A copy of this Economic Analysis is attached at Attachment A to these comments. The many problems with the Corps' economic analysis are discussed in Section VII.D. of these comments.

¹⁴⁰ DEIS at 9.

this information is critical for determining whether the Project is actually needed and will produce a positive return on the taxpayer's investment, the Corps is required as a matter of law to obtain this information, unless the cost of doing so is exorbitant.¹⁴¹

Despite decades of studying this Project, the Corps has not provided the most basic information concerning agricultural activities within the Project area.¹⁴² The DEIS does not provide the total number of farms that would be affected by the Project, the total value of products sold from those farms, or any estimates of crop damage or other agricultural losses caused by flooding in the Project area.

The DEIS does not provide the elevation of farms located within the Project area even though **all** project benefits are linked to the reduction of flooding at specific elevations. Without knowing the elevation of the farms in the Project area it is not possible to assess what percentage of total farms (and thus, beneficiaries) might allegedly benefit from the Project.

The DEIS does not provide farm ownership information, so it is not possible to discern whether some landowners or corporations own multiple farms in the Project area. The DEIS also does not provide information on the amount, location and terms of existing flood easements already owned by the Federal government in the Project area and does not provide information regarding farm subsidy payment made in the Project area.

This information is critical for determining the project need, whether the project will produce a positive return on the taxpayers' investment, and how the benefits of this costly and destructive project will be distributed.

In addition to the many legal and policy reasons that dictate selection of the "no action" alternative, the following also make clear that there is no legitimate need for the TSP (we do not suggest that less damaging actions should not be taken to address urban flooding problems in the St. Johns Bayou Basin):

1. Landowners in the New Madrid Floodway are knowingly and voluntarily operating in an area that has always flooded and that is designated as a relief valve during significant flood events.
2. Landowners in the New Madrid Floodway have already been paid by the Federal government to allow the land to flood. The Federal government currently owns flowage easements on at least 111,840 acres of land in the New Madrid Floodway.¹⁴³ The St. John Levee and Drainage District also appears to own easements covering 57,000 acres within the backwater area.¹⁴⁴
3. Despite – and far more likely, because of – existing flood regimes, the area has a significant amount of prime farmland. "The farmland found in the project area is some of the most

¹⁴¹ 40 C.F.R. § 1502.22.

¹⁴² While the DEIS does provide county wide information on the number of farms, total commodities sold, and farm subsidy payments, large portions of each county are located outside the Project area and would be unaffected by the Project.

¹⁴³ By 1942, the Federal government had purchased flowage easements on 106,858 acres of land in the New Madrid Floodway. By 1974, the Federal government had purchased modified flowage easements on 80,982 acres in the New Madrid Floodway, including 76,000 acres that were under the originally purchased easements. Mississippi River Commission Information Paper, *Mississippi River & Tributaries Project: Birds Point-New Madrid Floodway*, at 7, 11.

¹⁴⁴ *Id.* at 10.

productive found within the State of Missouri as well as the United States. The productivity of the farmland in the project area is so significant that it warrants special status from the USDA as prime and unique.”¹⁴⁵

4. Information contained in the DEIS makes clear that farming can proceed even after major flooding events. After the flood of 2011, “farmers were able to plant upwards of 90,000 acres of soybeans by the summer of 2011 and an additional 30,000 acres of soybeans or corn by spring 2012” in the New Madrid Floodway.¹⁴⁶
5. As discussed below, many landowners in the Project area are already receiving significant federal farm subsidy payments, which calls into question the appropriateness of (and national interest in) providing additional subsidies through construction of the Project.
6. Despite claiming 22 percent of project benefits for avoiding the need to raise I-55 to avoid flooding (which the Corps values at an average annual savings of \$3,439,000), the Missouri Department of Transportation advised the St. John’s Drainage District that the cost of keeping I-55 open during the 2011 floods was approximately \$163,000, and that the existing system of levees and pumps designed to protect I-55 have only been used “a few times.”¹⁴⁷ This suggests that the Corps has vastly overstated the need for the Project to protect I-55 and that the benefits claimed by the Corps for avoiding damage to I-55 are entirely without support and based on nothing but wishful (and wild) speculation.

Moreover, the natural flood regime, which serves to enrich the soil, is one of the primary reasons why farmland in the Project area is so productive. It is thus not surprising that at least one study strongly suggests that the Project would actually harm – not help – agricultural production in the Project area¹⁴⁸

This study looked at the riverine hydrological and regional climatic regime relationships to agriculture (cotton, soybeans) and the principal riverine fish stocks in the upper Yazoo River basin. The study looked at 31 years of data (from 1964 to 1994) to compare flooding in the study area with soybean and cotton production. It found that “no factor associated with flood events adversely influence production of cotton and soybeans. However, with regard to soybeans, the amount of area flooded two years prior to a crop was positively related to soybean yield. From a long-term perspective therefore, the data suggest that flooding may benefit agricultural enterprises associated with soybean production.”¹⁴⁹ The study also found that cotton yield was positively correlated with maximum area flooded during the same year, noting that this was likely due to increased soil moisture which benefits cotton production. This was true even though floods resulted in fewer acres of cotton being planted during flood years.¹⁵⁰

The study did note, however, that a different pattern appeared to emerge over shorter time periods “which may explain the public perception that flooding adversely impacts agriculture in the area. During

¹⁴⁵ DEIS at 216.

¹⁴⁶ DEIS at 8.

¹⁴⁷ DEIS, Volume II, Part 2, June 21, 2011 Letter from Stan Johnson, Area Engineer, Missouri Department of Transportation to St. John’s Draining District.

¹⁴⁸ Jackson, D. C. and Q. Ye. 2000. Riverine fish stock and regional agronomic responses to hydrologic and climatic regimes in the upper Yazoo River basin. Pages 242-257 in I. G. Cowx, Editor. Management and Ecology of River Fisheries. Fishing News Books. Blackwell Science. London.

¹⁴⁹ Id.

¹⁵⁰ Id.

the 5 year period from 1990-1994, high precipitation was negatively related to area planted in cotton and the percent of the area planted in soybeans that was actually harvested. However, flooding during this period did not significantly affect overall yield of cotton and soybeans.”¹⁵¹ And again, there was a positive correlation between cotton yields and the maximum area flooded during the same year.

That same study also shows that flooding benefits fisheries in the area, finding a positive relationship between flooding and positive fish stock characteristics, which the study defines as more and bigger fish. The study also noted that much of the productive potential for fisheries in floodplain river ecosystems is determined by the dynamics of overbank flooding and riparian vegetation.¹⁵²

Federal Farm Subsidy Payments

The DEIS states that as of “2007, there were 350 and 228 farms in New Madrid County and Mississippi County with an average size of 1,088 acres and 1,134 acres, respectively. . . . Total government farm subsidy payments were \$13,667,000 (with a per farm average of \$42,845) in New Madrid County, and \$4,459,000 (with a per farm average of \$22,294) in Mississippi County.”¹⁵³ However, large portions of each county are located outside the Project area so that the average farm subsidy payments in each county do not necessarily provide an accurate estimate of farm subsidy payments in the Project area.

The Environmental Working Group Farm Subsidy database provides more recent and comprehensive information on subsidy payments for New Madrid and Mississippi Counties. From 1995 to 2012, total farm subsidy payments for New Madrid County were \$443 million.¹⁵⁴ From 1995 to 2012, total farm subsidy payments for Mississippi County were \$185 million.¹⁵⁵

In an attempt to establish a more accurate assessment of farm subsidy payments in the Project area, the Conservation Organizations compared farm ownership data in the lower portion of the New Madrid Floodway from plat maps with farm subsidy data compiled by the Environmental Working Group.¹⁵⁶ While this information is not definitive, we believe it provides a more accurate assessment for purposes of evaluating whether it is in the national interest to provide more federal subsidies to farmers in this area by constructing the Project largely at federal taxpayer expense.

This analysis revealed that between 1995 and 2012, thirty entities¹⁵⁷ that own land in the New Madrid Floodway received \$8.89 million in farm subsidy payments for farming carried out in the Floodway.¹⁵⁸ Payments to individual entities ranged from \$17,195 to more than \$1.52 million. Of those entities that received farm subsidy payments, 8 received more than \$538,000 in payments during this period, and 21 entities received more than \$109,000.

¹⁵¹ Id.

¹⁵² Id.

¹⁵³ DEIS at 6-7.

¹⁵⁴ Environmental Working Group, New Madrid County, Missouri Summary Information, EWG Farm Subsidy Database (visited November 15, 2013)

¹⁵⁵ Environmental Working Group, Mississippi County, Missouri Summary Information, EWG Farm Subsidy Database (visited November 15, 2013).

¹⁵⁶ Environmental Working Group, EWG Farm Subsidy Database, (visited November 15, 2013).

¹⁵⁷ For purposes of this analysis, the Conservation Organizations consolidated various owners, companies, and trusts that could reasonably be determined to belong to the same person or family. To protect the privacy of the entities we have not included the detailed information with these comments, however, this information is on file with the National Wildlife Federation and will be supplied directly to the Corps upon request.

¹⁵⁸ We identified 21 entities that received no subsidy payments.

C. The DEIS Fails to Evaluate a Full Range of Reasonable Alternatives that Would Cause Far Less Harm to the Environment

As discussed in Section IV.B. of these comments, the DEIS fails to evaluate a full range of reasonable alternatives, including a host of alternatives that alone or in combination would provide extensive flood damage reduction benefits while also protecting the environment and providing benefits to the public at large. As also discussed in Section IV.B. of these comments, the limited analysis of some less damaging alternatives that is included in the DEIS is fundamentally flawed. Indeed, the Corps' alternatives analysis appears to have been improperly designed to justify a decision that had already been reached. The Corps' failure to fully evaluate a full range of reasonable alternatives violates the requirements outlined below, and renders its analysis inadequate as a matter of law.

An EIS must inform the decisionmakers and the public of reasonable alternatives that would avoid or minimize adverse impacts, and must provide a full and fair discussion of significant environmental impacts.¹⁵⁹ NEPA requires that each EIS "[r]igorously explore and objectively evaluate all reasonable alternatives."¹⁶⁰ This requires a **"thorough consideration of all appropriate methods of accomplishing the aim of the action"** and an **"intense consideration of other more ecologically sound courses of action."**¹⁶¹ The rigorous and objective evaluation of all reasonable alternatives to a proposed project is the "heart of the environmental impact statement."¹⁶²

The alternatives analysis must "[i]nclude reasonable alternatives not within the jurisdiction of the lead agency."¹⁶³ This requires the Corps to evaluate reasonable alternatives that are outside of the scope of the Corps' mission areas and those outside of the scope of a Congressionally authorized project.

While an EIS need not explore every conceivable alternative, it must rigorously explore all reasonable alternatives that are consistent with its basic policy objective and that are not remote or speculative. A viable but unexamined alternative renders an EIS inadequate.¹⁶⁴ In addition, an alternative may not be disregarded merely because it does not offer a complete solution to the problem.¹⁶⁵

Failure to look at an appropriate range of alternatives likewise renders an alternatives analysis inadequate.¹⁶⁶ The range of alternatives that must be considered is determined by the nature and scope of the proposed action. Thus, the greater the impacts and scope of the proposed action, the

¹⁵⁹ 40 C.F.R. § 1502.1.

¹⁶⁰ 40 C.F.R. § 1502.14.

¹⁶¹ *Environmental Defense Fund, Inc. v. Corps of Engineers of U.S. Army*, 492 F.2d 1123, 1135 (5th Cir. 1974) (emphasis added).

¹⁶² 40 C.F.R. § 1502.14.

¹⁶³ 40 C.F.R. § 1502.14(c).

¹⁶⁴ *E.g. Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810, 814 (9th Cir. 1999).

¹⁶⁵ *Natural Resources Defense Council, Inc. v. Morton*, 458 F.2d 827, 836 (D.C. Cir. 1972).

¹⁶⁶ *E.g. Resources Ltd., Inc. v. Robertson*, 35 F.3d 1300, 1307 (9th Cir. 1993).

greater the range of alternatives that must be considered.¹⁶⁷ The range of alternatives considered is not sufficient if each alternative has the same end result.¹⁶⁸

Importantly, “the discussion of alternatives must be undertaken in good faith; it is not to be employed to justify a decision already reached.”¹⁶⁹

D. The DEIS Economic Analysis Is Arbitrary, Unreliable, and Insufficient

The economic analysis contained in the DEIS is wholly insufficient to demonstrate that the TSP is economically justified or to support a federal investment in a \$165 million project that will have such significant, unmitigatable impacts.

A detailed economic analysis of the DEIS prepared by Donald C. Sweeney II, Ph.D. (the Sweeney Report) is attached to these comments at Attachment A, and the Conservation Organizations incorporate the entire contents of the Sweeney report into these comments as though fully set forth herein.¹⁷⁰ Dr. Sweeney is eminently qualified to evaluate the Project. Dr. Sweeney is a Teaching Professor of Logistics and Operations Management, an Affiliate Professor of Economics, and the Associate Director of the Center for Transportation Studies at the University of Missouri-St. Louis. He holds a Bachelor of Science degree in Mathematics and Economics from Knox College, Galesburg IL and a Ph.D. degree in Economics from Washington University, St. Louis MO. Prior to joining the University of Missouri-St. Louis in January 2005, Dr. Sweeney was employed by the Corps for 27 years as a regional economist, supervisory regional economist and senior regional economist.

The Sweeney Report concludes that the “economic analysis should be considered unreliable and insufficient to determine whether or not the recommended alternative, or any other alternative for that matter, will likely produce a positive net economic return for taxpayers’ investments.”¹⁷¹ The Sweeney Report also concludes:

“The economic analysis in the DEIS lacks the scope, data, detail, quality of execution and quality of presentation required to support such an important and controversial public policy decision involving the commitment of between \$58 and \$180 million of scarce resources (depending on the alternative implemented) with such potentially large environmental consequences. The analysis relies on arbitrary assumptions. Important specific and significant project-area supporting data is lacking. In many instances the descriptions of the analytical methodologies employed are insufficient to determine what was actually done, in other instances no descriptions of employed methodologies are provided at all, in still other instances, the

¹⁶⁷ *Alaska Wilderness Recreation and Tourism v. Morrison*, 67 F.3d 723, 729 (9th Cir. 1995); see *Sierra Club v. Espy*, 38 F.3d 792, 803 (5th Cir. 1994) (the range of alternatives that must be considered in an environmental assessment decreases as the environmental impact of the proposed action becomes less and less substantial).

¹⁶⁸ *State of California v. Block*, 690 F.2d 753, 767 (9th Cir. 1982) (holding that an inadequate range of alternatives was considered where the end result of all eight alternatives evaluated was development of a substantial portion of wilderness).

¹⁶⁹ *Citizens Against Toxic Sprays, Inc. v. Bergland*, 428 F.Supp. 908, 933 (D.Or. 1977).

¹⁷⁰ Donald C. Sweeney II, Ph.D., A Review of the Economic Analysis Presented in the St. Johns Bayou and New Madrid Floodway July 2013 Draft Environmental Impact Statement, Prepared for the National Wildlife Federation and the Great Rivers Environmental Law Center, November 8, 2013.

¹⁷¹ Sweeney Report at 2.

employed methodologies appear questionable at best. Further, the economic analysis is fraught with both demonstrable and apparent errors. The results of the 2013 DEIS Economic Analysis should not be used as a basis for any public policy decision.”¹⁷²

The Sweeney Report further states that “for the DEIS to be useful in informing a public policy decision of this magnitude” it should include: “(1) accurate data truly representing the existing conditions at various flood frequencies and elevations in the project area must be obtained and verified; (2) using that data, the errors in the current execution of the economic analysis must be acknowledged and corrected with updated and certified models; and (3), finally, the real levels of uncertainty present in the analysis and results must be identified, acknowledged and reported.”¹⁷³

The Sweeney Report discusses the many failings with the economic analysis in detail. A number of these failings are summarized below:

- Despite having decades to evaluate the Project (the Corps has prepared NEPA reviews for this Project in 1976, 1982, 2002, 2006, and 2013), the Corps has not bothered to obtain any actual data on flood damages or to document the elevation of any of the farms, roads, or structures that will allegedly benefit from the Project. As the Sweeney Report notes:

“Properly establishing the existing conditions is a fundamental first step to completing a meaningful economic analysis. Historical data should serve as the foundation for determining existing conditions which in turn then serve as the foundation for forecasting future conditions with and without project alternatives. Despite the contention that the study area is frequently flooded, evidence of historical flooded acres and actual flood related economic damages are not presented in the economic analysis.”¹⁷⁴

- “All of the estimated economic benefit categories ultimately derive from the reduction of flood risk. For that reason the economic analysis should have begun with a detailed identification and evaluation of the extent of without-project flooding. This should have been followed by an evaluation of the flooding risk under each distinct alternative. The DEIS and Economics Appendix did not accomplish this.”¹⁷⁵
- The DEIS Economic Appendix is rife with inconsistencies and basic math errors that lead to flawed conclusions. For example, the Sweeney Report concludes that it “appears that the annual expected flooding predicted in the 5-year floodplain is overestimated by at least a factor of 3.”¹⁷⁶ This could translate into benefits also being overestimated by a factor of 3 “because the estimated benefits are directly proportional to the expected flooding [so that] the apparent over-estimation of flooding will produce a corresponding over-estimation of the crop damage reduction benefits.”¹⁷⁷ The Sweeney Report further concludes that “even if the quantity of flooding were not an issue, the failure to definitively establish the ‘existing conditions’ together

¹⁷² Sweeney Report at 22-23.

¹⁷³ Sweeney Report at 23.

¹⁷⁴ Sweeney Report at 3.

¹⁷⁵ Sweeney Report at 7.

¹⁷⁶ Sweeney Report at 12.

¹⁷⁷ Sweeney Report at 12, 14.

with the uncertainty in forecasting the future condition would make it difficult to be confident in these estimations.”¹⁷⁸

- The Economic models have not been explained and appear not to have been certified. “Reliance is placed on a barely explained model, the Corps’ “Crop Flood Damage Analysis” (CFDA) model, to provide the agricultural crop damage reduction benefit estimates. Volume 3 of the 2013 DEIS provides certification reviews of many of the models used in preparation of the DEIS. The certification review of the CFDA is notably absent. The main body of the DEIS indicates in Figure S.1 (page V) that economic models should be part of the review and certification process. The absence of documentation suggests that this review and certification of economic models may not have occurred.”¹⁷⁹
- The Corps claims 22 percent of Project benefits “for avoiding expensive improvements to Interstate 55 that would be ‘required’ in the future in the without project condition.”¹⁸⁰ The Corps values the average annual savings from avoiding these improvements at \$3,439,000. Despite accounting for almost a quarter of the alleged project benefits, however, the Economic Appendix allots only one paragraph to discussing this benefit.

The Sweeney Report identifies three significant problems with this claimed benefit: (1) the cost estimate for raising I-55, which is the estimated benefit used by the Corps, was prepared by the Corps without the input of the Missouri Department of Transportation; (2) there is no evidence presented that the raising of I-55 is in itself a justified project; and (3) the DEIS provides no economic based rationale to justify raising I-55.¹⁸¹

In addition, the Corps has not explained how the project will prevent flooding of that stretch of highway. The Conservation Organizations believe that is highly questionable as to whether the Project would have any impact at all on reducing flood damages to I-55. The DEIS states that I-55 is not affected by flooding at all until at least the 10 year flood event, and that it can remain open with sandbagging and other efforts through at least a 50 year event.¹⁸² However, we have been informed that I-55 was affected by flooding in 2011 and 2008, but prior to that had not been affected by flooding since the 1970s.¹⁸³ The 2008 and 2011 floods have been estimated as being 500-year flood events. The Corps has not provided any explanation as to how St. Johns Bayou Basin portion of the Project (the only portion of the TSP for which the I-55 benefits are assessed), which is focused on reducing backwater and smaller scale flooding, would be able to reduce flood damages to the highway during major flood events.

Moreover, during both 2008 and 2011, the Missouri Department of Transportation was able to keep the highway open by constructing levees around the highway and using sandbags and water pumps, suggesting that raising the highway is unnecessary and would be an extremely low priority for the state. The Missouri Department of Transportation advised the St. John’s Drainage District that the cost of keeping I-55 open during the 2011 floods was approximately

¹⁷⁸ Sweeney Report at 14.

¹⁷⁹ Sweeney Report at 7.

¹⁸⁰ Sweeney Report at 19.

¹⁸¹ Sweeney Report at 19.

¹⁸² DEIS at 8-9.

¹⁸³ Personal communication with Missouri Department of Transportation staff.

\$163,000, and that the existing system of levees and pumps designed to protect I-55 have only been used “a few times.”¹⁸⁴ Indeed, we have also been informed that the Missouri Department of Transportation has had only general discussions about the flooding of I-55 and has not conducted any type of analysis to determine whether it would be appropriate to raise I-55.¹⁸⁵ As a result, the 22 percent of Project benefits claimed by the Corps for avoiding damage to I-55 are entirely without support and based on nothing but wishful (and wild) speculation.

In short, the economic analysis in the DEIS can best be described as an embarrassing effort on the part of the Corps. It cannot be relied upon to demonstrate that the Project is economically justified as required by law.

E. The DEIS Significantly Understates the Wetland Impacts and Overstates the Value of Mitigation

The DEIS significantly underestimates the wetland impacts of the Project. The DEIS underestimates the farmed wetland impacts by more than 9,000 acres. The DEIS fails to evaluate any wetland impacts above the 5-year floodplain. The DEIS fails to properly evaluate the adverse impacts that will result from changes in the duration and inundation on wetlands in the Project area. As also discussed in Section V. of these comments, the DEIS fails to provide scientifically or legally sound mitigation for the significant adverse impacts of this Project.

A detailed analysis of the wetland assessment and mitigation plan in the DEIS prepared by Dr. Joy Zedler (the 2013 Zedler Report) is attached to these comments at Attachment B, and the Conservation Organizations incorporate the entire contents of the 2013 Zedler Report into these comments as though fully set forth herein.¹⁸⁶ Dr. Zedler is eminently qualified to evaluate the Project. Dr. Zedler is a Professor of Botany and Aldo Leopold Chair in Restoration Ecology at the University of Wisconsin. She has published more than 250 peer reviewed publications and has participated in four panels of the National Research Council, including as Chair of the National Research Council Panel on *Compensating for Wetland Losses Under the Clean Water Act*.

The 2013 Zedler Report concludes that the analyses provided by the U.S. Environmental Protection Agency (EPA) as part of an interagency team is particularly convincing regarding the large quantity of farmed wetlands in the Project area. EPA used accepted interagency mapping conventions and combined those with field studies. These mapping conventions are designed to show evidence of inundation from multiple sources, not merely backwater flooding. As Dr. Zedler notes, “[t]here is no reason to doubt the EPA assessment.”¹⁸⁷ Copies of materials related to EPA’s wetland assessments are attached to these comments at Attachment C.

FWS notes that even though EPA and FWS used different methodologies in their wetlands assessments for the Project, the agencies “are surprisingly consistent in their estimates of wetlands within the proposed project area.”¹⁸⁸ The Corps’ failure to accurately distinguish farmed wetlands from prior

¹⁸⁴ DEIS, Volume II, Part 2, June 21, 2011 Letter from Stan Johnson, Area Engineer, Missouri Department of Transportation to St. John’s Draining District.

¹⁸⁵ Personal communication with Missouri Department of Transportation staff.

¹⁸⁶ Dr. Zedler’s 2006 Report is also attached to these comments at Attachment B.

¹⁸⁷ 2013 Zedler Report at 4.

¹⁸⁸ *Id* at 18.

converted cropland “accounts for the biggest divergence between the three agencies’ estimates,”¹⁸⁹ and according to FWS underestimates the project’s wetland impacts by 10,000 or more wetland acres.¹⁹⁰

Significantly, the Corps’ own hydrologic analysis of backwater flooding establishes that there are at a minimum approximately 9,174 acres of farmed wetlands that will be all, or partially drained, by the Project.¹⁹¹ That figure is based on the precise Corps analysis of the timing and extent of flooding in the Project area showed in the hydraulics appendix. However, the DEIS fails to acknowledge these wetlands and thus fails to acknowledge these significant impacts.

The DEIS also understates the wetland impacts of the Project by failing to evaluate any wetlands above the 5-year floodplain. As the Zedler Report notes, the “DEIS indicates the Corps’ intent to ignore impacts on these wetlands on the theory that they are little influenced by backwater flooding. It is true that the flooding from the river will not be the principal source of water for these wetlands, but further reduction in flooding is likely to alter these wetlands as well. These impacts therefore should be counted.”¹⁹² By failing to evaluate the impacts the impacts to wetlands and fish and wildlife from hydrologic changes above the 5 year floodplain, the DEIS fails to account for the full suite of aquatic impacts as required by law.¹⁹³

Significantly, the Department of the Interior “has consistently” told the Corps that the Hydrogeomorphic Method (HGM) that is used “did not include all of the potentially affected wetlands” and that the model is “insensitive to hydrological changes and other important factors.”¹⁹⁴ This is a significant failure as even small alterations in wetlands hydrology can produce significant and ecosystem-wide changes. As the seminal textbook on wetlands states:

“When hydrologic conditions in wetlands change even slightly, the biota may respond with massive changes in species composition and richness and in ecosystem productivity.”¹⁹⁵

Indeed, “[h]ydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes,” and even “small changes in hydrology can result in significant biotic changes.”¹⁹⁶ This is because:

Hydrology affects the species composition and richness, primary productivity, organic accumulation, and nutrient cycling in wetlands. . . . Water depth flow patterns, and duration and frequency of flooding, which are the result of all the hydrologic inputs and outputs, influence the biochemistry of the soils and are major factors in the ultimate selection of the biota of wetlands. . . . Hydrologic conditions can directly modify or change chemical and physical

¹⁸⁹ *Id.*

¹⁹⁰ *Id.* at 23-24.

¹⁹¹ Zedler Report at 4-5; DEIS Appendix C.

¹⁹² Zedler Report at 3.

¹⁹³ The Conservation Organizations also note that while the Corps has not evaluated impacts above the 5-year floodplain it has claimed benefits above the 5-year floodplain, including for example, claiming 22% of Project benefits for avoiding the need to elevate Interstate 55, which the DEIS states is not affected by flooding until a 10 year flood and with sandbagging and other efforts can be kept open through at least a 50 year flood. See DEIS at 8-9, and Section VII.D. of these comments.

¹⁹⁴ *Id.* at cover letter page 2.

¹⁹⁵ William J. Mitsch and James G. Gosselink, *Wetlands* (2nd ed.) (1993) at 68 (emphasis added).

¹⁹⁶ *Id.* at 68.

properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties, and pH.¹⁹⁷

As a result the impacts from even small changes in the duration and extent of inundation of wetlands in the Project area must be evaluated as such changes will likely create significant adverse affects to fisheries, wildlife habitat, water quality, water quantity, soil moisture recharge, deposition of sediments and nutrients, and flood pulse conditions.

The Department of the Interior has also concluded that the DEIS “does not account for forested wetlands that will be lost as a result of being cleared due to post-project drainage and agricultural conversion” because the Corps has restricted “its evaluation to the construction footprint and does not include the reasonably foreseeable indirect effects to forested wetlands caused by the changes in land use and hydrologic changes.”¹⁹⁸

Dr. Zedler also notes that the Corps has consistently understated the ecological value of the Project site:

“At various places, the DEIS attempts to disparage the ecological value of the project site on the grounds that it is altered both hydrologically, through alteration of the Mississippi River’s basic flows, and vegetatively, through clearing of most of the land for agriculture. It is true that these alterations somewhat alter and somewhat reduce the ecological functions. But virtually all aquatic ecosystems in the United States are heavily altered. The project area is as close to providing the functions of natural floodplains as can exist almost anywhere on the lower Mississippi River. It would be more accurate to say that in such a changed system, the persistence of the critical elements of floodplain functions by the project makes this site more important, not less.”¹⁹⁹

As discussed in detail in Section V. of these comments, the mitigation proposed by the Corps is scientifically unsound and legally inadequate. Dr. Zedler is one of the country’s leading wetland scientists and chaired a panel of the National Academy of Sciences at the request of the Corps and EPA to provide guidance on appropriate wetland mitigation. In her report, Dr. Zedler provides an extensive analysis of the problems with the Corps’ proposed mitigation including the following:

- The Project conflicts with modern scientific understanding of wetland mitigation because it eliminates extensive inundated habitat and proposes to mitigate without restoring inundation to any areas. Instead, its mitigation is based on artificial, engineered manipulation of hydrology on already inundated sites, and reforestation of already flooded lands, and by a small percentage of the impacted area. Doing so conflicts with the core principles of wetland mitigation, which are that natural hydrology should be preserved, along with spatial extent of aquatic habitat, landscape position, and habitat complexity and that mitigation should avoid engineering structures to manage hydrology.
- The new mitigation in the DEIS for the Project primarily relies on mitigation the Corps itself previously did not claim: such as claims that Big Oak Tree State Park would provide fish habitat or that extensive areas of the batture lands would provides suitable fish habitat.

¹⁹⁷ *Id.* at 67-68.

¹⁹⁸ *Id.* at Specific Comments page 11.

¹⁹⁹ Zedler Report at 3.

- The Corps' use of HEP models violates the recommendations for appropriate wetland impact and mitigation analysis because it focuses on limited attributes of habitat, oversimplifies species needs, and assumes that artificial management of small areas can replace natural flooding of larger areas. HEP models also make many judgments about the needs of different species with little or no evidence. The change of focus of wetland mitigation away from these kinds of habitat models recognized their inadequacy and that the full complement of wetland and other aquatic functions required that mitigation reproduce the more natural conditions of the aquatic areas to be lost.

F. The DEIS Significantly Understates the Fisheries Impacts and Overstates Fisheries Mitigation

A detailed analysis of impacts of fisheries and the ecological value of the Project mitigation for fisheries prepared by Richard Sparks, Ph.D. (the Sparks Report), is attached to these comments at Attachment D, and the Conservation Organizations incorporate the entire contents of this report into these comments as though fully set forth herein. Dr. Sparks is one of the country's leading fish biologists and has served on numerous panels of the National Academy of Sciences. Dr. Sparks has spent most of his career focusing on the Mississippi River system and his publications include the seminal publication on the importance of the flood pulse to understanding large river systems.

The Sparks Report analyzes the numerous flaws with the fisheries analysis in the DEIS and with the mitigation that has been proposed for the Project as it relates to fisheries. These flaws include the following:

- The DEIS greatly underestimates the impacts of reduced fish access due to the levying off of the floodway. The Corps' analysis claims that this levee closure will reduce the value of flooded habitat in the project area by only 27 percent. But this analysis is fundamentally flawed as it at best purports to examine only the impact on fish access when the gates are open. An even more basic problem is that the gates will be closed during roughly two thirds of the fish spawning and rearing seasons, even when there is just minimal flooding at 280 feet or above. Even more significantly, the gates will be closed during the overwhelming majority of days when flood levels would generate substantial habitat.
- The Corps' exclusion of much of the agricultural area of the project on the grounds that it does not meet certain hydrologic criteria is logically inconsistent with the recognition of rearing habitat, and is otherwise scientifically invalid.
- Contrary to the Corps' claims, the proposed mitigation sites within the New Madrid Floodway are unlikely to support virtually any spawning and rearing fish because they are at elevations that require the gates to be closed before backwater floodwaters reach them. That includes the large mitigation claimed for Big Oak Tree State Park. As Dr. Sparks elaborates, the impacts of the project are greatly underestimated because of the problem of fish access, and the benefits of mitigation are greatly overestimated.
- The DEIS fisheries analysis greatly underestimates the impact on permanent floodplain lakes and greatly overvalues the impact of mitigation by creating new floodplain lakes through borrow pits and levees. The result is that a few hundred acres of floodplain lake mitigation is incorrectly projected to offset the impact of reduced or eliminated inundation on thousands of acres of forest and agricultural land in key seasons.

- The mitigation sites proposed in the DEIS that will have fish access are not likely to provide valuable suitable habitat. Many of these acres would involve reforestation in the land between the levees, the batture lands. But these lands do not have the appropriate temperature or calm waters during significant floods for fish spawning and rearing equivalent to the backwater floodplain, nor do they provide the mosaic of habitats of the existing project area:

"This review indicates that all of the proposed mitigation sites offer limited potential mitigation for fish. Reforestation of areas within the floodplain will provide areas with extremely limited access by fish. Reforestation of batture lands is unlikely to provide habitat of equivalent value for spawning and rearing because of the high velocities and low temperatures. Digging of open water areas in the batture lands is likely to create habitat that will be rapidly silted in, and the changes to Riley Lake proposed are adverse: reducing fish access to already existing habitat."²⁰⁰

The Sparks report also demonstrates how the fish analysis is inconsistent with modern scientific understanding of the key attributes of fish habitat and is otherwise overly simplistic. The accepted scientific principles recognize the importance of the multiple attributes of the Project site and particularly the fundamental importance of hydrology and that these vast impacts cannot be offset by more intensive vegetative management of much smaller areas without restoring inundation to any areas that are not now subject to inundation.

G. The DEIS Significantly Overstates Shorebird Mitigation

A detailed analysis of Project impacts on shorebirds and waterfowl prepared by Bruce Dugger, Ph.D. (the Dugger Report) is attached to these comments at Attachment E, and the Conservation Organizations incorporate the entire contents of this report into these comments as though fully set forth herein. Dr. Dugger is a prominent shorebird and waterfowl expert who is also familiar with the project site through site visits and through his work for many years at a nearby University.

The Dugger Report concludes that the Project site provides ecologically important shorebird habitat:

"The connectivity between the river and floodplain in the New Madrid Floodway creates a unique wetland complex for migrating shorebirds along the Mississippi River Drainage. Although data about shorebird use of the project site are lacking, the large area of diverse floodplain wetlands scattered across the New Madrid Floodway/St. Johns Bayou area provides habitat for a wide range of shorebird species. Species commonly using floodplain wetlands in the project area include Pectoral Sandpiper (*Calidris melanotos*), Semipalmated Sandpiper (*Calidris pusilla*), Least Sandpiper (*Calidris minutilla*), Lesser Yellowlegs (*Tringa flavipes*), Greater Yellowlegs (*Tringa melanoleuca*), and Common Snipe (*Gallinago gallinago*). Shorebirds require habitats that are shallow and sparsely vegetated, thus flooded agriculture wetlands and seasonal herbaceous (moist soil) wetlands are the most important resource to shorebirds in the project area. Although farmed wetlands have limited value for some species of wildlife, they offer valuable shorebird habitat because disking and plowing set back vegetation succession keeping these wetlands available for shorebirds (Helmert 1992)."²⁰¹

²⁰⁰ Sparks Report at 18.

²⁰¹ Dugger Report.

Dr. Dugger also concludes that the proposed shorebird mitigation is not adequate. As explained in the Dugger Report, the Corps' mitigation is based on a shorebird model that calculates the average availability of extremely shallow habitat on open lands that shorebirds can use through the 93-day shorebird migrating season in the spring. It calculates that these flooded areas provide the equivalent of 935 optimal flooded acres per day. The Corps then assumes that equivalent acreage could be supplied by managing an impoundment of 1,280 acres to be flooded all 93 consecutive days every year, which the Corps asserts will provide the equivalent "optimal" habitat given their depths. However, Dr. Dugger identifies several major problems with this assumption.

First, achieving these habitats by keeping one small area flooded all 93 days will not provide comparable food resources as would exist without the Project. The Project area currently provides habitat and food resources by the flooding of tens of thousands of acres for shorter periods. When shorebirds use the same acres (as they would under the proposed mitigation), they deplete available food supplies. However, when shorebirds utilize moving areas of shallow habitat (as they do under existing conditions) flood supplies remain relatively fresh. Failure to account for this is a fundamental misapplication of the model.

Second, the Corps plans to obtain the great majority of its shorebird habitat by claiming credit for 10 Mile Pond. But 10 Mile Pond already exists and would continue to exist regardless of the Project, so it cannot provide suitable mitigation for new Project impacts. Meanwhile reforestation would further reduce shorebird habitat.

Dr. Dugger does not address the legal issues regarding the claimed use of 10 Mile Pond, but the Corps' new position is not legally justified. It is interesting that through the prior six versions of the EIS, the Corps never claimed that 10 Mile Pond could be used to provide new mitigation. However, the Corps now claims it can do so by relying on the 1986 authorization, but that language is inappropriate on its face. That authorization provided in part, "except that lands acquired by the State of Missouri after January 1, 1982, for mitigation of damage to fish and wildlife within the Ten Mile Pond mitigation area shall be counted as part of the total quantity of mitigation lands required for the project and shall be maintained by such State for such purpose." This language explicitly refers to "damage to fish and wildlife within the Ten Mile Pond mitigation area" that would be caused by the project. As a result, it permits the mitigation site to be counted as mitigation for project impacts that occur solely on those lands.

Regardless of the merits of the Corps' new interpretation of this language, it is in any event superseded by 33 U.S.C. 2283(d)(3) (A), which was enacted in 2007. Among other things, this section provides:

"To mitigate losses to flood damage reduction capabilities and fish and wildlife resulting from a water resources project, the Secretary shall ensure that the mitigation plan for each water resources project complies with the mitigation standards and policies established pursuant to the regulatory programs administered by the Secretary."

The mitigation standards and policies established pursuant to these regulatory programs do not allow mitigation credit for prior activities undertaken by separate parties (except as part of an approved mitigation bank). The Corps cannot now claim mitigation credit for these independent actions taken by independent bodies that were completed long ago.

H. The DEIS Significantly Understates the Waterfowl Impacts

The Dugger Report also discusses waterfowl impacts, which are also inadequately mitigated. Although Dr. Dugger believes that the Corps has improved its Waterfowl Assessment Model (WAM), he concludes that the fundamental problem remains that this tool is designed solely to address the feeding needs of mallards and wood ducks. It does not address their other needs.

More importantly, it does not address the needs of the large numbers of other duck species that also use the project area, and that while their numbers are smaller, are to some extent therefore of even greater conservation concern. These ducks do not consume many of the foods analyzed by WAM, and do not use their forested habitats, generally preferring more open water areas. Even to the extent the WAM model properly accounts for the food needs of mallards and wood ducks, it therefore cannot be used properly to analyze overall project impacts or the adequacy of mitigation. The Corps has failed to propose mitigation for these additional species, for whom the loss of flooded agricultural lands and marshes is extremely important and which the “mitigation” further reduces.

The Dugger Report also raises serious questions with the estimates of energy food production from many of the mitigation sites on which the Corps relies.

I. The DEIS Fails to Evaluate Impacts on Amphibians and Reptiles

The DEIS devotes a scant three paragraphs to the impacts of the Project on amphibians and reptiles.²⁰² Those paragraphs, which cite just one scientific study, conclude that some species will benefit from the project and some will be impacted, and that habitat changes to amphibians and reptiles would be represented by habitat changes calculated for other species. This is entirely inadequate to properly evaluate the impacts to any species, let alone to species like amphibians and reptiles that are facing unprecedented risks of extinction. The significant underestimate of wetland impacts and the significant underestimate of the adverse impacts that would result from the loss of connectivity between the river and floodplain further undermine the “analysis” of impacts to these at risk species.

It is well established that wetlands are extremely important to amphibians (frogs, toads, newts) and reptiles (snakes, turtles), and many endangered and threatened amphibian and reptile species are especially linked to wetlands. The enormous wetland losses and habitat fragmentation from the Project puts these species at particular risk in the Project area. This danger is amplified by the fact that amphibian populations are in precarious state world-wide.

In the United States, the IUCN Red List of Threatened Species lists 56 amphibian species and 37 reptile species as known to be critically endangered, endangered, or vulnerable.²⁰³ Worldwide, at least 1,950 species of amphibians are threatened with extinction of which 520 species are critically endangered, 783 are endangered, and 647 species are vulnerable. This represents 30 percent of all known amphibian

²⁰² DEIS at 138.

²⁰³ IUCN Red List version 2013:2, Table 5: Threatened species in each country (totals by taxonomic group), available at http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table5.pdf (visited on November 24, 2013.)

species.²⁰⁴ In 2004, scientists estimated that most of 1,300 other amphibian species are also threatened though sufficient data are currently lacking to be able to accurately assess the status of those species.²⁰⁵ The IUCN Red List of Threatened Species also lists 879 species of reptiles as threatened with extinction worldwide, which represents 21 percent of all evaluated reptile species.²⁰⁶

A recent study demonstrates the increasingly dire conditions of amphibians worldwide:

“Current extinction rates are most likely 136–2707 times greater than the background amphibian extinction rate. These are staggering rates of extinction that are difficult to explain via natural processes. No previous extinction event approaches the rate since 1980 (Benton and King, 1989).”

“Despite the catastrophic rates at which amphibians are currently going extinct, these are dwarfed by expectations for the next 50 yr (Fig. 1). If the figure provided by Stuart et al. (2004) is true (but see Pimenta et al., 2005; Stuart et al., 2005), one-third of the extant amphibians are in danger of extinction. This portends an extinction rate of 25,000–45,000 times the expected background rate. Episodes of this stature are unprecedented. Four previous mass extinctions could be tied to catastrophic events such as super volcanoes and extraterrestrial impacts that occur every 10 million to 100 million years (Wilson, 1992). The other mass extinction seems to be tied to continental drift of Pangea into polar regions leading to mass glaciation, reduced sea levels, and lower global temperatures (Wilson, 1992). The current event far exceeds these earlier extinction rates suggesting a global stressor(s), with possible human ties.”²⁰⁷

As noted in the July 2013 Draft Fish and Wildlife Coordination Act Report, the Project area provides vital habitat for amphibians and reptiles:

“Johnson (1997) notes that the native swamplands of southeast Missouri provide unmatched habitat for many species of amphibians and reptiles. Amphibians expected to occur on stream and lake edges, ponds, and in forested wetlands in the project area include the western lesser siren, marbled and small mouth salamanders, Fowler’s toad, eastern narrow-mouthed toad, spring peeper, green treefrog, and bronze frog. Wetlands in the project area also support a number of State-listed rare species including the three-toed amphiuma, Illinois chorus frog, and the eastern spadefoot toad.”²⁰⁸

²⁰⁴ IUCN Red List version 2013:2, Table 3a: Status category summary by major taxonomic group (animals), available at http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table3a.pdf (visited on November 24, 2013).

²⁰⁵ Science Daily, *Amphibians In Dramatic Decline; Study Finds Nearly One-Third Of Species Threatened With Extinction* (October 15, 2004), available at <http://www.sciencedaily.com/releases/2004/10/041015103700.htm> (visited on November 24, 2013).

²⁰⁶ IUCN Red List version 2013:2, Table 3a: Status category summary by major taxonomic group (animals), available at http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table3a.pdf (visited on November 24, 2013).

²⁰⁷ McCallum, M. L. (2007). “Amphibian Decline or Extinction? Current Declines Dwarf Background Extinction Rate.” *Journal of Herpetology* 41 (3): 483–491. doi:10.1670/0022-1511(2007)41[483:ADOECD]2.0.CO;2.

²⁰⁸ July 2013 Draft U.S. Fish and Wildlife Service Fish and Wildlife Coordination Act Report, DEIS Appendix Q, Part 1 at 8.

“Reptiles found in sloughs, swamps, ditches, oxbows, and ponds in the project area include Mississippi mud turtle, stinkpot, southern painted turtle, State-listed rare western chicken turtle, red-eared slider, alligator snapping turtle and the eastern spiny softshell, broadhead skink, black rat snake, State-listed rare dusky hognose snake, speckled king snake, water snakes, western ribbon snake, eastern garter snake, and rough green snake. This exceptional floral and faunal diversity at the study area can be traced to dynamic water levels, nutrients, and energy associated with connection to the Mississippi River.”²⁰⁹

“Many species of amphibians throughout the project area require shallow waters to successfully reproduce. In addition to permanent ponds, sloughs, and ditches, spring flooding can cover up to 75,000 acres in the New Madrid Floodway alone. As those waters recede, they create thousands of ephemeral ponds critical to maintaining a healthy and diverse amphibian population. Habitats with variable flooding regimes have been shown to support highly diverse herptofauna. Work by Galat et al. (1998) documented differential use and abundance of reptiles and amphibians in a variety of wetland types. For example, connected scours were dominated by false map turtles and softshells; remnant wetlands had more sliders and painted and snapping turtles. Scour holes contained to the river contained the highest species richness. Remnant wetlands had the more species of salamanders and snakes than other types of wetlands. Those various wetland types also supported a diverse bird assemblage, where species use of a particular type of wetlands appeared to depend on wetland size, structural diversity, and depth. In addition, flooding increases invertebrate biomass, which becomes an important protein source for waterfowl and shorebirds on their migration to northern breeding grounds (Helmert 1992, Reinecke et al. 1989).”²¹⁰

The Fish and Wildlife Coordination Act report also concludes that:

“Project implementation is also expected to negatively affect reptiles and amphibians in the project area. Eliminating seasonal backwater flooding over thousands of acres, and the ephemeral ponds that remain after flood waters recede will significantly reduce suitable habitat for reptiles and amphibians, particularly during spring breeding. In addition, project-related changes to surface water patterns may eliminate ponding in many areas in all but the wettest years. This would not only reduce available habitat, but further fragment and isolate tracts of remaining habitat and their reptile and amphibian populations.”²¹¹

“Fish and wildlife species with limited mobility (i.e., reptiles and amphibians) will experience a net loss of habitat within the project area that will not be compensated through the proposed mitigation lands.”²¹²

Some of the most common dangers to species survival are habitat destruction, fragmentation, and alteration – the very impacts that would result from the Project.

²⁰⁹ *Id.*

²¹⁰ *Id.* at 15.

²¹¹ *Id.* at 31.

²¹² *Id.* at iii and 50.

Amphibians thrive in cool wetland environments, and are found in all types of wetlands except more saline coastal environments. Small, isolated wetlands play especially important roles in amphibian productivity.²¹³

Amphibian populations thrive when there are a variety of small ecosystems within a regional landscape in which a “dynamic equilibrium” of different populations becomes established.²¹⁴ However, if the environment becomes overly fragmented, the dynamic equilibrium is disturbed because patterns of emigration and immigration may be disrupted.

Amphibians spend part of their life cycles in an aquatic environment and part in a terrestrial environment (typically returning to water to breed). For example, some salamanders undergo larval development within an aquatic environment, and then live along wet streamsides following metamorphosis into adult stages. Those that do not breed in water still need moist environments to prevent extreme dehydration.²¹⁵ The tadpoles of most frog species develop in ponds, lakes, wet prairies, and other still bodies of water, while others are known to breed in a wide variety of wetland habitats. As adults, toads, frogs and some salamanders can travel relatively great distances from water sources, but they return to water to reproduce.

Agricultural practices can have negative impacts on amphibian populations. In addition to replacing natural habitat with foreign species, agriculture can dramatically change the ecosystem. For example, on the southeastern Coastal Plain, where pine plantations have replaced the native longleaf pine savanna, ditches to speed water runoff caused thousands of acres of wetlands to disappear. Ditching between ponds to facilitate water transfer can shorten hydroperiods for amphibian larval development. Ditching wetlands lowers water tables, subsequently changing the local vegetation and altering or eliminating hydroperiods. Studies have demonstrated that unditched ponds, on the other hand, have greater amphibian species richness during dry periods,²¹⁶ which is especially important for those pond-breeding species that return to breeding sites.

Land use changes caused by activities such as road building can also affect amphibian populations in a number of ways. In addition to the dangers of habitat fragmentation mentioned above,²¹⁷ roads can separate overwintering sites from breeding sites and increase mortality as animals attempt to cross. For example, one study showed that as few as 26 vehicles per hour on one road prevented any toads from

²¹³ Gibbons, J. Whitfield, Christopher Winne, et. al. 2006. Remarkable Amphibian Biomass and Abundance in an Isolated Wetland: Implications for Wetland Conservation. *Conservation Biology* Volume 20, No. 5, 1457–1465.

²¹⁴ Mann, W., P. Dorn, and R. Brandl. 1991. Local distribution of amphibians: The importance of habitat fragmentation. *Global Ecology and Biogeography Letters* 1:36-41.

²¹⁵ Semlitsch, R. D. 1987. Relationship of pond drying to the reproductive success of the salamander *Ambystoma talpoideum*. *Copeia* 1987:61-69; Pechmann, J. H. K., D. E. Scott, J. W. Gibbons, and R. D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetlands Ecology and Management* 1:3-11.

²¹⁶ Harris, L. D. and C. R. Vickers. 1984. Some faunal community characteristics of cypress ponds and the changes induced by perturbations. In *Cypress Swamps*. K. C. Ewel, and H. T. Odum (eds.). University Presses of Florida, Gainesville, FL, p. 171-185; Vickers, C. R., L. D. Harris, and B. F. Swindel. 1985. Changes in herpetofauna resulting from ditching of cypress ponds in coastal plains. *Forest Ecology and Management* 11:17-29.

²¹⁷ Laan, R., and B. Verboom. 1990. Effects of pool size and isolation on amphibian communities. *Biological Conservation* 54:251-262; Sjogren, P. 1991b. Genetic variation in relation to demography of peripheral pool frog populations (*Rana lessonae*). *Evolutionary Ecology* 5:248-271.

crossing it.²¹⁸ Land use changes that destroy environments can also alter the breeding habits of amphibians. For example, building U.S. Highway 44 in 1963 caused toxic silt from roadfill to spill into the local aquatic environment, eliminating nearly all aquatic life downstream of the road.²¹⁹

Recent studies also point to the role of global climate change in promoting potentially catastrophic impacts to amphibian populations. For example:

- Global climate change will result in changes to weather and rainfall patterns that can have significant adverse effects on amphibians. Drought can lead to localized extirpation. Cold can induce winterkill in torpid amphibians. It is possible that the additional stress of climate change, on top of the stresses already created by severe loss of habitat and habitat fragmentation may jeopardize many amphibian species.²²⁰
- Recent studies suggest that climate change may be causing global mass extinctions of amphibian populations. Particularly alarming is the fact that many of these disappearances are occurring in relatively pristine area such as wilderness areas and national parks.²²¹ One recent study suggests that climate change has allowed the spread of a disease known as chytridiomycosis which has led to extinctions and declines in amphibians. Climate change has allowed this disease to spread by tempering the climate extremes that previously kept the disease in check.²²² About two-thirds of the 110 known harlequin frog species are believed to have vanished during the 1980s and 1990s because of the chytrid fungus *Batrachochytrium dendrobatidis*. Other studies indicate that amphibians may be particularly sensitive to changes in temperature, humidity, and air and water quality because they have permeable skins, biphasic life cycles, and unshelled eggs.²²³
- Climate change may also affect amphibian breeding patterns.²²⁴ Amphibians spend a significant part of the year protecting themselves from cold or shielding themselves from heat. They receive cues to emerge from their shelters and to migrate to ponds or streams to breed from

²¹⁸ Heine, G. 1987. Einfache Meß- und Rechenmethode zur Ermittlung der Überlebenschance wandernder Amphibien beim Überqueren von Straßen. Beihefte zu den Veröffentlichungen Naturschutz und Landschaftspflege Baden-Württemberg 41:473-479.

²¹⁹ Mathews, R. C., Jr., and E. L. Morgan. 1982. Toxicity of Anakeesta Formation leachates to shovel-nosed salamander, Great Smoky Mountains National Park. Journal of Environmental Quality 11:102-106.

²²⁰ Sjogren, P. 1993a. Metapopulation dynamics and extinction in pristine habitats: A demographic explanation. Abstracts, Second World Congress of Herpetology, Adelaide, Australia, p. 244; Sjogren, P. 1993b. Applying metapopulation theory to amphibian conservation. Abstracts, Second World Congress of Herpetology, Adelaide, Australia, p. 244-245.

²²¹ Pounds, J. A., and M. L. Crump. 1994. Amphibian declines and climate disturbance: The case of the golden toad and the harlequin frog. Conservation Biology 8:72-85; Lips, K. R. 1998. Decline of a Tropical Montane Amphibian Fauna. Conservation Biology 12:106-117; Lips, K., F.Brem, R. Brenes, J.D. Reeve, R.A. Alford, J. Voyles, C. Carey, L. Livo, A. P. Pessier, and J.P. Collins 2006. Emerging infectious disease and the loss of biodiversity. Proceedings of the National Academy of Sciences 103:3165-3170.

²²² Pounds, J.A., M.P.L. Fogden, J.H. Campbell. 2006. Biological response to climate change on a tropical mountain. Nature 398, 611-615.

²²³ Carey, C., and M. A. Alexander. 2003. Climate change and amphibian declines: is there a link? Diversity and Distributions 9:111-121.

²²⁴ Carey, C., and M. A. Alexander. 2003. Climate change and amphibian declines: is there a link? Diversity and Distributions 9:111-121.

subtle increases in temperature or moisture. As the earth warms, one potential effect on amphibians is a trend towards early breeding, which makes them more vulnerable to snowmelt-induced floods and freezes common in early springs. Some studies already indicate a trend towards earlier breeding in certain amphibian species.²²⁵

- Increases in UV-B radiation in the northern hemisphere due to ozone depletion is also having an adverse impact on amphibians.²²⁶ One study suggests that ultraviolet-B (UV-B) radiation adversely affects the hatching success of amphibian larvae.²²⁷ High levels of UV-B also induced higher rates of developmental abnormalities and increased mortality in certain species (*Rana clamitans* and *R. sylvatica*) than others that were shielded from UV-B.²²⁸ UV-B also can have detrimental effects on embryo growth.

Given these stressors, the additional impacts of the Project could be catastrophic for amphibian and reptile species in the Project area. The failure of the DEIS to adequately evaluate the impacts to these species (along with the failure to adequately assess the impacts to wetlands and the impacts of the lost connectivity between the river and floodplain) render the DEIS grossly inadequate.

J. The DEIS Significantly Understates the Cumulative Impacts

The cumulative impacts analysis ensures that the reviewing agency will not “treat the identified environmental concern in a vacuum.”²²⁹ Cumulative impacts are defined as:

“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.”²³⁰

While the DEIS provides information on the impacts of past activities, it provides little meaningful insight into the implications of those activities when combined with the adverse impacts of the Project. The cumulative impacts analysis also fails to provide a meaningful analysis of the impacts of present and reasonably foreseeable future activities, or the implications of those activities when combined with the adverse impacts of the Project.

²²⁵ Beebee, T. J. C. 1995. Amphibian Breeding and Climate. *Nature* 374:219-220; Blaustein, A. R., L. K. Belden, D. H. Olson, D. M. Green, T. L. Root, and J. M. Kiesecker. 2001. Amphibian breeding and climate change. *Conservation Biology* 15:1804-1809; Gibbs, J. P., and A. R. Breisch. 2001. Climate warming and calling phenology of frogs near Ithaca, New York, 1900-1999. *Conservation Biology* 15:1175-1178.

²²⁶ Blumthaler, M., and W. Ambach. 1990. Indication of increasing solar ultraviolet-B radiation flux in alpine regions. *Science* 248:206-208; Kerr, J. B., and C. T. McElroy. 1993. Evidence for large upward trends of ultraviolet-B radiation linked to ozone depletion. *Science* 262:1032-1034.

²²⁷ Blaustein, A. R., P. D. Hoffman, D. G. Hokit, J. M. Kiesecker, S. C. Walls, and J. B. Hays. 1994a. UV repair and resistance to solar UV-B in amphibian eggs: A link to population declines? *Proceedings of the National Academy of Science* 91:1791-1795.

²²⁸ Grant, K. P., and L. E. Licht. 1993. Effects of ultraviolet radiation on life history parameters of frogs from Ontario, Canada. Abstracts, Second World Congress of Herpetology, Adelaide, Australia, p. 101.

²²⁹ *Grand Canyon Trust v. FAA*, 290 F.3d 339, 346 (D.C. Cir. 2002).

²³⁰ 40 C.F.R. § 1508.7.

For example, despite the well-recognized impacts of operation of the Upper Mississippi River Navigation System on the loss of backwater habitat²³¹ – and that fact that this system will continue to be operated in the very long term – the cumulative impacts analysis contains only one paragraph on the potential future impacts of the navigation system, and that paragraph does not discuss the implications of continued loss of backwater or other vital habitat in connection with the adverse impacts of the Project. The DEIS also fails to evaluate the cumulative impact of the New Madrid levee on flood heights when combined with the many other flood control and navigation structures (including river training structures) in and along the Mississippi River and the Project area.²³²

In evaluating cumulative impacts:

“The analyst’s primary goal is to determine the magnitude and significance of the environmental consequences of the proposed action in the context of the cumulative effects of other past, present, and future actions. Much of the environment has been greatly modified by human activities, and most resources, ecosystems, and human communities are in the process of change as a result of cumulative effects. **The analyst must determine the realistic potential for the resource to sustain itself in the future and whether the proposed action will affect this potential; therefore, the baseline condition of the resource of concern should include a description of how conditions have changed over time and how they are likely to change in the future without the proposed action.** The potential for a resource, ecosystem, and human community to sustain its structure and function depends on its resistance to stress and its ability to recover (i.e., its resilience). Determining whether the condition of the resource is within the range of natural variability or is vulnerable to rapid degradation is frequently problematic. Ideally, the analyst can identify a threshold beyond which change in the resource condition is detrimental. More often, the analyst must review the history of that resource and evaluate whether past degradation may place it near such a threshold. For example, the loss of 50% of historical wetlands within a watershed may indicate that further losses would significantly affect the capacity of the watershed to withstand floods. **It is often the case that when a large proportion of a resource is lost, the system nears collapse as the surviving portion is pressed into service to perform more functions.**”²³³

Rather than conducting this important analysis, the DEIS simply concludes that the Project will not cause cumulative impacts because the project area is already degraded and the Project includes mitigation. This demonstrates a fundamental lack of understanding of how to conduct an appropriate cumulative

²³¹ See e.g., U.S. Geological Survey, *Ecological Status and Trends of the Upper Mississippi River System 1998: A Report of the Long Term Resource Monitoring Program* (April 1999); Johnson, B. L., and K. H. Hagerty, editors. 2008. U.S. Geological Survey, *Status and Trends of Selected Resources of the Upper Mississippi River System*, December 2008, Technical Report LTRMP 2008-T002. 102 pp + Appendixes A–B (Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin).

²³² See *Sierra Club v. U.S. Army Corps of Engineers*, 494 F. Supp. 2d 1090, 1096 (W.D. Mo. 2007) (The Corps’ conclusion that the proposed levee would not create a significant change in the flood profile was arbitrary and capricious because the Corps failed to consider the cumulative impact of adding the proposed levee to the flood control structures already in place.).

²³³ Council on Environmental Quality, *Considering Cumulative Effects Under the National Environmental Policy Act* (January 1997) at 41.

impacts analysis, and a stunning lack of understanding of the vital importance of the river-floodplain connection.²³⁴

Notably, the cumulative impacts analysis in the DEIS completely ignores – and makes no reference at all – to a fundamentally different conclusion reached by the independent external peer review panel convened to evaluate the DEIS:

“The panel believes that the New Madrid Floodway is unique because, in context, it is the last remaining connection between the Mississippi River and its floodplain in the State of Missouri. Therefore, it plays a much larger role in providing natural floodplain services than the other areas. If the other originally connected areas had not been disconnected, the Floodway would be playing a proportionally smaller, and less important, role in maintaining the natural ecosystem. **The loss of this last remaining connection and its ecosystem functioning would be the “straw that broke the camel’s back” in terms of the total cumulative impact.** That is, not all incremental impacts are equal and it is the impact that exceeds a threshold that is significant. In this case, the adverse impact of removing the last floodplain connection, once the other connections have already been removed, is disproportionately high.”²³⁵

In the IEPR Phase 3 document, the independent external peer review panel again concluded that the Project would have a significant cumulative impact and expressed additional concerns with the Corps’ cumulative impacts analysis:

“The DEIS assigns little value to the ecosystem services (e.g., carbon sequestration) provided by floodplain connection to the Mississippi River, based on the argument that the system has been significantly changed over time. However, the Panel believes that the ecological value of the remaining connection to the Mississippi River is high. As described in CEQ (1997), the loss of this last remaining connection is an example where additional impacts, no matter how small, will have a disproportionate cumulative effect by exceeding the threshold where floodplain connection ecosystem functioning is eliminated. **The Panel believes that closing the last connection would have a significant cumulative impact on the flood-dependent system.** While it is not required that a project compensate for historical impacts, **it is incumbent on the project not to contribute the incremental impact that may cause the project to exceed this overall threshold.**

The value of the flood-dependent system can be characterized in terms of ecosystem services such as carbon and nitrogen sequestration (Costanza et al. 1997). Throughout the DEIS, ecosystem services are not considered or are undervalued, while economic benefits may be inflated and based on previous socioeconomic data, particularly given the major changes in the Floodway after the 2011 floods.”²³⁶

²³⁴ Even a cursory review of the scientific literature would reveal the significant importance of maintaining this last remaining natural connection between the river and its floodplain in the state of Missouri. Similarly, a cursory review of the scientific literature would demonstrate the falsity of the Corps’ claim that the ecological consequences of the Mississippi River and Tributaries Project “are only starting to be understood.” DEIS at 216.

²³⁵ DEIS Volume 3 Part 3, Phase 2 IEPR at B-43.

²³⁶ DEIS Volume 3 Part 4, Phase III IEPR Final Comment Response Record at 61 (emphasis added).

“Where scientists disagree about possible adverse environmental effect, the EIS must inform decision-makers of the full range of responsible opinion on the environmental effects.’ Where the agency fails to acknowledge the opinions held by well respected scientists concerning the hazards of the proposed action, the EIS is fatally deficient.”²³⁷ It is not sufficient to include the statements of the panel in an Appendix or to refer to the panel’s position in responses to the Final Comment Response Record, they must be included and appropriately responded to in the cumulative impacts section of the DEIS.²³⁸

The Conservation Organizations also note that the cumulative impacts analysis highlights the high value and productivity of the farmland in the Project area,²³⁹ which begs the question of why it would ever be considered a wise investment of taxpayer dollars to spend at \$165 million on a project that will cause devastating environmental harm in order to increase the productivity of these already highly productive lands.

K. The DEIS Fails to Adequately Evaluate the Impacts of Climate Change

The effects of global warming on the Mississippi River and its floodplain, and on the species that rely on the floodplain, wetlands, and river-floodplain connectivity in the Project area are potentially quite significant. As a result, the EIS must carefully consider whether the impacts of climate change could exacerbate the impacts of the Project.²⁴⁰ Unfortunately, the climate change analysis in the DEIS falls far short of the rigorous analysis required by NEPA.

Because the DEIS fails to consider the impacts of climate change on the fish and wildlife resources that rely on the wetlands and river-floodplain connectivity that would be lost through the Project, the DEIS understates the adverse impacts of the TSP. The DEIS also understates the adverse impacts of the TSP because it fails to evaluate the extent to which the TSP would render the species that rely on these resources less resilient to climate change.

The Council on Environmental Quality has advised all Federal agencies that the magnifying and additive effects of global warming must be evaluated when examining the direct, indirect, and cumulative impacts of a proposed action:²⁴¹

²³⁷ *Friends of the Earth v. Hall*, 693 F. Supp. 904, 934 (W.D. Wash. 1988)(citations omitted).

²³⁸ *Id.*

²³⁹ DEIS at 216 (“The farmland found in the project area is some of the most productive found within the State of Missouri as well as the United States. The productivity of the farmland in the project area is so significant that it warrants special status from the USDA as prime and unique.”)

²⁴⁰ 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 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.”).

²⁴¹ 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. Council on Environmental Quality, *Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions* (February 18, 2010).

“Climate 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.”²⁴²

For example, climate change may cause significant adverse impacts for the many migratory species that utilize the Project area, and these impacts must be considered in evaluating the impacts of the Project particularly in the context of the cumulative impact analysis. As recognized by the United Nations Environment Program and the Convention on the Conservation of Migratory Species of Wild Animals:

“As a group, migratory wildlife appears to be particularly vulnerable to the impacts of Climate Change because it uses multiple habitats and sites and use a wide range of resources at different points of their migratory cycle. They are also subject to a wide range of physical conditions and often rely on predictable weather patterns, such as winds and ocean currents, which might change under the influence of Climate Change. Finally, they face a wide range of biological influences, such as predators, competitors and diseases that could be affected by Climate Change. While some of this is also true for more sedentary species, migrants have the potential to be affected by Climate Change not only on their breeding and non-breeding grounds but also while on migration.”

“Apart from such direct impacts, factors that affect the migratory journey itself may affect other parts of a species’ life cycle. Changes in the timing of migration may affect breeding or hibernation, for example if a species has to take longer than normal on migration, due to changes in conditions *en route*, then it may arrive late, obtain poorer quality breeding resources (such as territory) and be less productive as a result. If migration consumes more resources than normal, then individuals may have fewer resources to put into breeding”

* * *

“Key factors that are likely to affect all species, regardless of migratory tendency, are changes in prey distributions and changes or loss of habitat. Changes in prey may occur in terms of their distributions or in timing. The latter may occur though differential changes in developmental rates and can lead to a mismatch in timing between

²⁴² Council on Environmental Quality, *Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions* (February 18, 2010).

predators and prey (“phenological disjunction”). Changes in habitat quality (leading ultimately to habitat loss) may be important for migratory species that need a coherent network of sites to facilitate their migratory journeys. Habitat quality is especially important on staging or stop-over sites, as individuals need to consume large amounts of resource rapidly to continue their onward journey. Such high quality sites may [be] crucial to allow migrants to cross large ecological barriers, such as oceans or deserts.”²⁴³

Migratory birds are at particular risk from climate change. Migratory birds are affected by changes in water regime, mismatches with food supply, sea level rise, and habitat shifts, changes in prey range, and increased storm frequency.²⁴⁴

However, rather than taking the required hard look at how the impacts of the Project would be exacerbated by climate change, the DEIS uses this section to try to justify the project by asserting that “the project, combined with its compensatory mitigation, would result in significant cumulative benefits to the ecosystem within the immediate project area as well as the region.”²⁴⁵ At the most basic level, this conclusion is incorrect for two very fundamental reasons. First, the purpose of mitigation is to replace the resources lost to the project, so at the most basic level mitigation would simply replace the ecosystem services lost to the project (assuming that mitigation was successful). Second, as discussed at length in these comments, many experts have concluded that the adverse impacts of the Project cannot in fact be mitigated.

The DEIS admits that it does not account for the increased variability and extreme weather events that are the clearest signals of climate change, but instead bases its analyses solely on historical data.²⁴⁶ However, water managers now routinely warn against basing design considerations solely on historical conditions: “In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning.”²⁴⁷ This is because the climate change-induced variability will likely lead to more extreme weather, higher flows and more severe droughts than have been experienced in the past.

While the use of scenarios is as an appropriate way to plan for uncertainty, the particular scenarios used in the DEIS are not connected to particular emissions trajectories or likely climate change impacts, but instead appear simply to be different types of situations that are not necessarily mutually exclusive

²⁴³ UNEP/CMS Secretariat, Bonn, Germany, *Migratory Species and Climate Change: Impacts of a Changing Environment on Wild Animals* (2006) at 40-41 (available at http://www.cms.int/publications/pdf/CMS_ClimateChange.pdf).

²⁴⁴ *Id.* at 42-43.

²⁴⁵ DEIS at 234.

²⁴⁶ See e.g., DEIS at 229-230 (“The project design has been optimized for the climatic conditions experienced over the past seven decades. That analysis period in itself comprehends considerable variability in temperature and precipitation. An attempt to optimize the project for one or more possible climatic futures would deemphasize the significance of the existing data collected and modeled. Moreover, if the most widely accepted forecasts of climate change should occur, there is no reason to believe that the project would be economically unfeasible, or that project mitigation areas would perform unsatisfactorily.”); DEIS at 150 (“Since input data [into the HEP model] assumed stationarity, the model does not account for any future changes as it relates to climate change.”)

²⁴⁷ P.C.D. Milly, et al., *CLIMATE CHANGE: Stationarity Is Dead: Whither Water Management?*, Science February 2008, Vol 319 (5863), pp. 573-574, available at http://www.paztcn.wr.usgs.gov/julio_pdf/milly_et_al.pdf (visited November 2, 2013).

when planning across multiple years. In addition, rather than assessing different scenarios as they may affect fish and wildlife, the scenarios mostly distinguish between impacts to farmland (where flooding would cause economic harm) and non-farmland.

Indeed, possible impacts to shorebirds is the only wildlife related topic touched on in the climate change analysis, and this is limited to a few lines: “Although shorebirds may benefit from higher flood frequency elevations, shorebirds as a group would likely be very susceptible to sea level rises. Thus any potential increases in habitat would be negated by sea level rise along the coast.”²⁴⁸

The Corps should completely redo its climate change assessment to address the types of concerns raised in these comments and should ensure that it uses the most up to date climate science in this new review. The Conservation Organizations urge the Corps to begin its new review by utilizing the regional inputs to the National Climate Assessment. The Midwest assessment can be accessed at: http://glisa.msu.edu/great_lakes_climate/nca.php.

L. The DEIS Fails to Meaningfully Evaluate the Risk of Increased Flooding

The Corps has not carried out the necessary studies to determine whether construction of the New Madrid levee (i.e., closing the 1,500 foot gap) would itself increase flood heights. The DEIS relies on an evaluation conducted 23 years ago using a 1950s era physical model to evaluate the effect on flood heights of constructing the New Madrid levee.²⁴⁹ This dramatically outdated analysis is utterly unreliable; an accurate hydrologic analysis must be conducted using modern and verified models and modern data.

Physical models cannot be relied upon to provide accurate planning information as they lack “predictive capability.”²⁵⁰ Put another way, a physical model is wildly inadequate for predicting flood level effects.

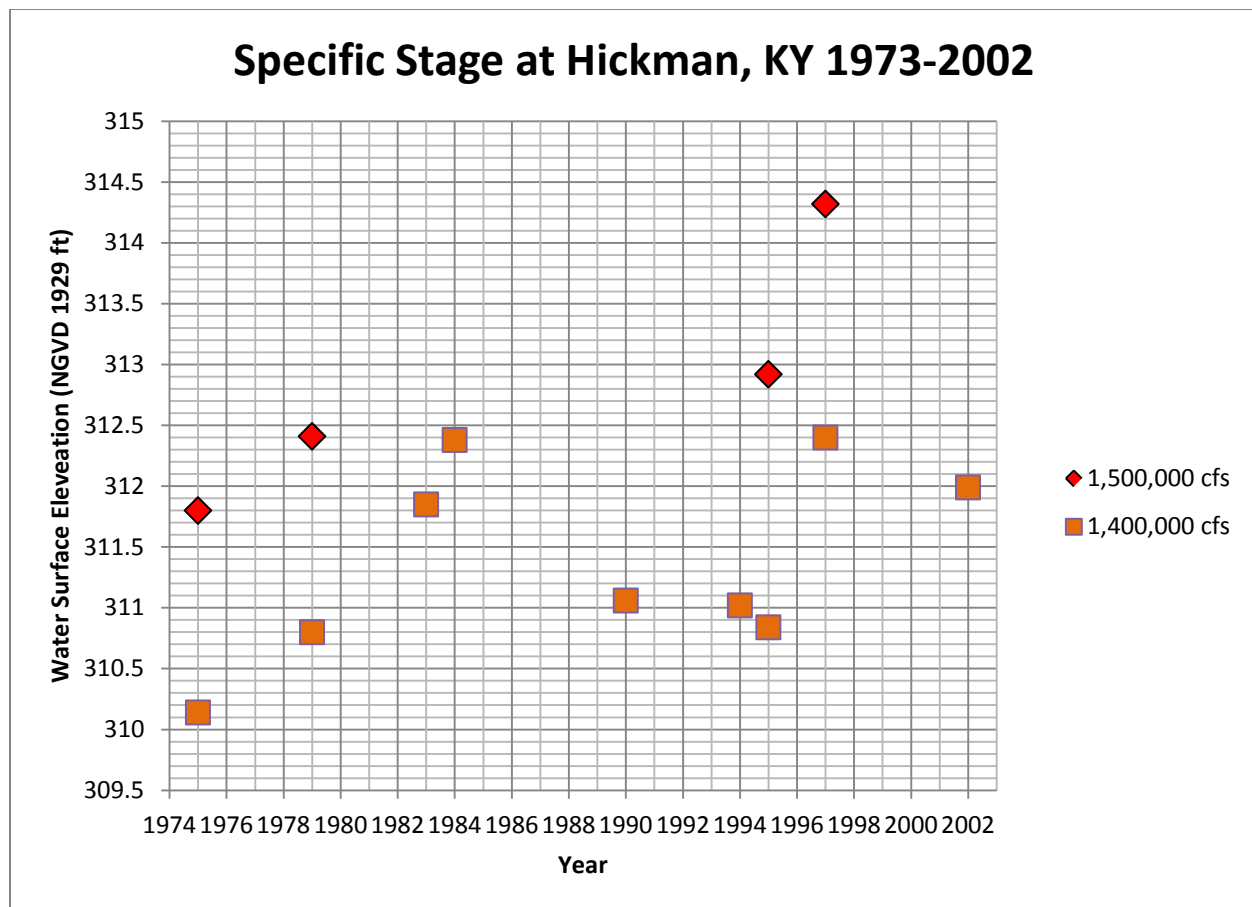
Even if a physical model could provide something close to an accurate prediction, a physical model developed in the 1950s would not be based on existing conditions in the river. Conditions have also changed significantly since the model was last run in 1990 (or possibly earlier). For example, the data below suggest that between 1974 and 2002, there has been 2.5 foot increase in water surface elevation for a moderate flood at Hickman, KY.²⁵¹

²⁴⁸ DEIS at 231.

²⁴⁹ DEIS Appendix C at C-18; Mississippi Basin Model Letter Report 89-1, Birds Point-New Madrid Floodway Reconnaissance Study, dated July 27, 1990 (“The MBM is of the fixed-bed type, reproducing a large portion of the Mississippi River and its major tributary system to a horizontal scale of 1:2000 and a vertical scale of 1:100. General features of the model, including appurtenances, instrumentation, and operating procedures, are discussed in detail in MBM Report 1-4, DESCRIPTION OF THE MISSISSIPPI BASIN MODEL, dated 18 July 1951.”)

²⁵⁰ Stephen T. Maynard, Journal of Hydraulic Engineering, *Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model* (April 2006). While Maynard’s study reviewed a micromodel, the same problems hold true for larger scale physical models. Maynard concludes that because of the “lack of predictive evidence, micromodel should be limited to demonstration, education, and communication.”

²⁵¹ Pinter, N. Jemberie A. A., Remo J.W.F, Heine, R.A., Ickes B.S. 2010. Cumulative Impacts of River Engineering, Mississippi and Lower Missouri Rivers. River Research and Applications. DOI10.1002/rra.1269; Pinter, N., A. A. Jemberie, J. W. F. Remo, R. A. Heine, B. S. Ickes, 2008. Flood trends and river engineering on the Mississippi River system, Geophys. Res. Lett., 35, L23404, DOI:10.1029/2008GL035987.



Source: ²⁵²

Given the potential public safety implications, it is essential that the Corps completely reassess the impacts of the TSP on flood heights using a state of the art 2-D hydrodynamic model with inputs that recognize the current conditions in the river system. In the absence of such modeling, the Corps cannot conclude that this project will not cause risks to public safety by increasing the risk of flooding during small and large scale flood events.

The Conservation Organizations also note that the Corps' 23 year old analysis shows that the Project would in fact increase flood heights by a significant amount. That analysis concludes that construction of the levee would increase flood heights at Hickman, Kentucky by 0.1 feet, at the riverside of the mainline levee near Big Oak Tree State Park by 0.3 feet, and at levee mile 81 of the Mississippi River frontline levee by 0.5 feet (according to information provided to the Conservation Organizations by the Corps this levee mile is located just above the Donaldson Point Conservation Area). These are significant flood height increases, and of course are not confined to just the precise locations measured by the Corps. For example, minimum standards for the State of Illinois limit such increases in flood heights to 0.1 foot, provided that hazardous velocities are not produced.²⁵³ The DEIS incorrectly concludes that

²⁵² *Id.*

²⁵³ Illinois State Water Survey Division, and Illinois Division of Water Resources, Governor's Task Force on Flood Control, State of Illinois Guidelines for Flood Plain Studies, March 1975; Illinois Department of Transportation, Division of Water Resources, Rules and Regulations, Regulation of Construction Within Flood Plains Established Pursuant to Section 65f, Chapter 19, Illinois Revised Statutes, Springfield, Illinois, 1973. For purposes of the

these flood height increases are not significant.

The DEIS also fails to evaluate the potential impacts of the Project on delaying the activation of the New Madrid Floodway. The implications of such a delay are significant and are discussed in more detail below.

M. The DEIS Fails to Properly Assess the Risk of Disproportionate Impacts to Low Income and Minority Communities

Executive Order 12898 requires that each Federal agency achieve environmental justice by identifying and addressing disproportionately high adverse human health or environmental effects of federal activities on minority and low-income populations. The Project will disproportionately affect the health and safety of minority and low income populations by making it harder to utilize the New Madrid Floodway to reduce the risk of catastrophic flooding during severe floods.

The Corps has not carried out the necessary studies to determine whether construction of the New Madrid levee (i.e., closing the 1,500 foot gap) would itself increase flood heights in a way that would have a disproportionate impact on low income and minority communities. As discussed in Section VII.L. of these comments, the DEIS relies on an evaluation conducted 23 years ago using a 1950s era physical model to evaluate the effect on flood heights of constructing the New Madrid levee (closing the 1,500 foot gap).²⁵⁴ This dramatically outdated analysis is utterly unreliable; an accurate hydrologic analysis must be conducted using modern and verified models and modern data.

However, the Corps' 23 year old analysis shows that the Project would in fact have a disproportionate impact on low income and minority populations by increasing flood risks at Hickman, Kentucky (see census information for Hickman below). That analysis concludes that construction of the levee would increase flood heights at Hickman, Kentucky by 0.1 feet, at the riverside of the mainline levee near Big Oak Tree State Park by 0.3 feet, and at levee mile 81 of the Mississippi River frontline levee by 0.5 feet (according to information provided to the Conservation Organizations by the Corps this levee mile is located just above the Donaldson Point Conservation Area).

These are significant flood height increases, and of course are not confined to just the precise locations measured by the Corps. For example, minimum standards for the State of Illinois limit such increases in flood heights to 0.1 foot, provided that hazardous velocities are not produced.²⁵⁵

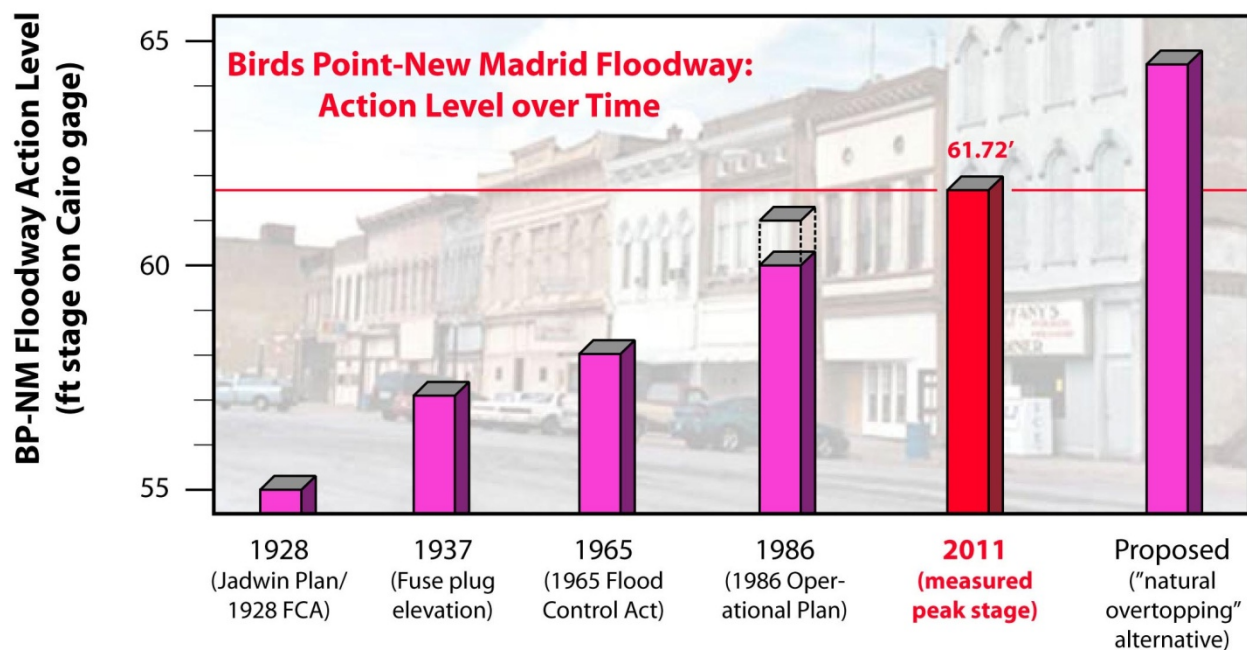
National Flood Insurance Program, FEMA establishes a maximum allowable increase of 1.0 foot, provided that hazardous velocities are not produced. FEMA Guide for Community Officials, Guide for Community Officials (December 2009), Chapter 7.

²⁵⁴ DEIS Appendix C at C-18; Mississippi Basin Model Letter Report 89-1, Birds Point-New Madrid Floodway Reconnaissance Study, dated July 27, 1990 ("The MBM is of the fixed-bed type, reproducing a large portion of the Mississippi River and its major tributary system to a horizontal scale of 1:2000 and a vertical scale of 1:100. General features of the model, including appurtenances, instrumentation, and operating procedures, are discussed in detail in MBM Report 1-4, DESCRIPTION OF THE MISSISSIPPI BASIN MODEL, dated 18 July 1951.")

²⁵⁵ Illinois State Water Survey Division, and Illinois Division of Water Resources, Governor's Task Force on Flood Control, State of Illinois Guidelines for Flood Plain Studies, March 1975; Illinois Department of Transportation, Division of Water Resources, Rules and Regulations, Regulation of Construction Within Flood Plains Established Pursuant to Section 65f, Chapter 19, Illinois Revised Statutes, Springfield, Illinois, 1973. For purposes of the National Flood Insurance Program, FEMA establishes a maximum allowable increase of 1.0 foot, provided that

Protecting communities from flooding is a fundamental objective of the Mississippi River & Tributaries program and timely activation of the floodway is an essential tool to protect communities. Prior Corps studies carried out for the Project show that levees and floodwalls would overtop in dozens of river communities in Illinois, Missouri and Kentucky if the New Madrid Floodway is not used during a severe flood.²⁵⁶ By promoting intensified use of the New Madrid Floodway, the Project will increase the pressure to prevent activation of the floodway which will make it even harder to operate the floodway to save towns in the area during the next big flood.

The pressure placed on the Corps to not utilize the floodway is significant, and the results of that pressure can be seen by the steadily increasing action levels at which the Corps is to activate the Floodway over time:



Action Level Chart Courtesy of Nicholas Pinter, Ph.D., Southern Illinois University

During the flood of 2011, activation of the New Madrid Floodway was delayed until well after the current activation level was reached despite advance notice of the flood threat. On April 30, the National Weather Service had predicted that the flood stage at Cairo would reach 61.5 feet by May 4.²⁵⁷

hazardous velocities are not produced. FEMA Guide for Community Officials, Guide for Community Officials (December 2009), Chapter 7.

²⁵⁶ St. Johns Bayou and New Madrid Floodway, Consolidated NEPA Document (consolidating the 2002 RSEIS and the 2006 RSEIS 2 for the St. Johns Bayou and New Madrid Floodway, MO Project), Appendix K. p. 13-14 (previously available at <http://www.mvm.usace.army.mil/stjohns/PeerReview/default.asp>; this document appears to have been removed from the Corps' website).

²⁵⁷ Camillo, Charles A., "Divine Providence: The 2011 Flood in the Mississippi River and Tributaries Project" (2012). *US Army Corps of Engineers, Omaha District*. Paper 142 at 93, available at <http://digitalcommons.unl.edu/usarmyceomaha/142> (visited on November 24, 2013).

On May 1, the river level at Cairo had surged past 59.5 feet.²⁵⁸ However, the Bird's Point levee was not blown up until May 2, 2011 at approximately 10 pm EST. By that time, the river had reached 61.72 feet at Cairo. "Missouri officials had fought hard to stop the plan, filing court actions all the way to the U.S. Supreme Court."²⁵⁹ The delay in activating the floodway has been implicated in the flooding of Olive Branch. After the floodway was activated in 2011, water levels at Cairo dropped 2.7 feet in just 48 hours.

Similar delays have occurred each time the Corps has anticipated activating the Floodway. In 1983, a lawsuit was filed that enjoined use of the floodway until April 1984; the Corps ultimately did not activate the Floodway during this flood event because the water levels did not reach the activation level. In 1937, the National Guard had to be called in to quell armed opposition to the floodway's use.

The communities most likely to be affected by delays in activating the New Madrid Floodway have significant minority and low-income populations:

United States Census Data ²⁶⁰			
Town	Poverty Level	Child Poverty	Minority Population
Cairo, IL	44.2%	71.7%	72.4% (69.6% African American)
Charleston, MO	29.8%	52.3%	53.3% (50.4 %African American)
Hickman, KY	26.1%	40.1%	36.1% (34.1% African American)
Paducah, KY	23.6%	40.0%	29.0% (23.7% African American)
East Prairie, MO	20.9%	18.8%	3.2% (2.7% African American)
Sikeston, MO	20.0%	28.0%	31.2% (26.2% African American)
East Cape Girardeau, IL	10.0%	14.6%	5.2% (3.4% African American)

N. The DEIS Fails to Properly Assess Impacts to Ecosystem Services

While the Conservation Organizations appreciate the Corps' inclusion of a discussion of ecosystem services in the DEIS, that discussion fails to properly assess the value of the ecosystem services that will be lost as a result of the Project.

Moreover, we fundamentally disagree with the Corps' conclusion that "Implementation of the preferred project alternative (New Madrid Floodway 3.1 and St. Johns Bayou Basin 2.1) would yield considerable gains in ecosystem services, both within the project area as well as in adjacent and downstream ecosystems primarily from mitigation necessary to compensate for impacts to fish and wildlife resources."²⁶¹ As noted elsewhere in these comments, the purpose of mitigation is to replace the resources lost to the project, so at the most basic level mitigation would simply replace the ecosystem services lost to the project (assuming that mitigation was successful). As also discussed at length in these comments, many experts have concluded that the adverse impacts of the Project cannot in fact be mitigated.

²⁵⁸ *Id.* at 94.

²⁵⁹ CBS St. Louis, <http://stlouis.cbslocal.com/2011/05/03/watch-blowing-up-birds-point-levee/> (visited on November 24, 2013).

²⁶⁰ United States Census Bureau, *American FactFinder*, available at <http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml> (last visited November 15, 2013).

²⁶¹ DEIS at 205.

In addition, a meaningful ecosystem services valuation would assess far more services than the two evaluated by the Corps. Significant progress has been made in the science of ecosystem services evaluation and many valuable assessments have been carried out. The Conservation Organizations refer the Corps to the three ecosystem services valuations attached at Attachment F 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.

The Conservation Organizations urge the Corps to contract with an organization expert in conducting ecosystem services valuations, and ensure that the ecosystem services that will be lost to the Project are accounted for as project costs in the benefit-cost analysis for the Project.

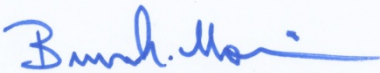
VIII. Conclusion

As discussed above, the Conservation Organizations strongly oppose the Project and urge the Corps to abandon it and select the no action alternative. Should the Corps continue to pursue the Project it must substantially rewrite the DEIS to address the many legal and scientific deficiencies discussed throughout these comments. Should the Corps choose to pursue the Project despite its critically significant and unacceptable environmental impacts, the Conservation Organizations call on the Environmental Protection Agency to veto the project under Section 404(c) of the Clean Water Act, and call on the Department of the Interior to refer the project to the Council on Environmental Quality pursuant to 42 U.S.C. § 4344.

Respectfully submitted,



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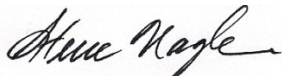
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Attachment A
Comments of the Conservation Organizations

On the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)

A Review of the Economic Analysis Presented in the St. Johns Bayou and New Madrid Floodway July 2013 Draft Environmental Impact Statement

PREPARED FOR THE NATIONAL WILDLIFE FEDERATION
AND THE GREAT RIVERS ENVIRONMENTAL LAW CENTER
NOVEMBER 8, 2013

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List of Attachments

Attachment 1: USDA Economic Research Service 2012 Normalized Prices

Attachment 2: USDA Economic Research Service 2012 State Level Normalized Prices

Attachment 3: Estimation of Expected Annual Flooding (Excel Spreadsheet)

Attachment 4: 2002 Revised Supplemental Environmental Impact Statement – Appendix B

Attachment 5: Biography of Donald C. Sweeney II, Ph.D.

I. Background

The Memphis District of the Corps of Engineers has published (July 2013) a Draft Environmental Impact Statement for the St. Johns Bayou New Madrid Floodway Project (DEIS) examining potential flood risk management projects (with significant environmental consequences) that affect the New Madrid Floodway (NMF) and St. Johns Bayou (SJBB) area. These areas are located near the Mississippi River in southeast Missouri. The 2013 DEIS is the latest in a long line of Corps' studies regarding these controversial projects since an earlier, less extensive, Corps project was first authorized by Congress in 1954.

Informed public policy decision making requires sound economic analysis. The analysis must be grounded in reality and based (to the extent possible) on observable data. When assumptions are necessary they should be reasonable, appropriate and clearly identified. Appropriate methodologies must be selected and executed without error. Finally, the data, assumption, methodologies, computations, and results should be made available for public review and comment.

This document reviews and comments on the Economic Analysis provided in the July 2013 DEIS. The economic analysis is detailed primarily in Appendix B of the DEIS.

II. General Findings

The economic analysis as presented in the DEIS lacks the scope, data, detail, quality of execution and quality of presentation required to support such an important and controversial public policy decision involving the commitment of between \$58 and \$180 million of scarce resources (depending on the specific alternative implemented) with such potentially large environmental consequences. What is presented in Appendix B of the DEIS appears to rely critically on arbitrary assumptions. Important and specific project-area data is lacking. In many instances the provided descriptions of the analytical methodologies employed are insufficient to determine what was actually done, in other instances no descriptions are provided at all. In still other instances the described methodologies appear questionable or inappropriate. Further, the 2013 DEIS and the economic analyses as represented in Appendix B are replete with both demonstrable and apparent errors. Given the above, the economic analysis should be considered unreliable and insufficient to determine whether or not the recommended alternative, or any other alternative for that matter, will likely produce a positive net economic return for taxpayers' investments.

III. Specific Deficiencies

A. Presentation

As an initial matter, unlike the DEIS or most of the other appendices, Appendix B is provided in a non-searchable (pdf) format. This inhibits the reader from finding specific information, or extracting data from the report for independent testing. Further, the document lacks page numbering and a structured outline. This makes it difficult for the reviewer to reference specific areas of the document.

The appendix lacks documentation of source information. For example, the FY12 normalized crop prices employed in the analysis are sourced to the USDA Economic Research Service, but the document does not indicate a specific report, provide a link, or append the report to the analysis.

The consistency between textual explanations and the tabular information could be greatly improved. For example, Table B-1 indicates a year of 2011; however the body of the report (under the paragraph labeled MRL Feature Data) indicates a base year of 2012. Further, this particular table indicates applicability to the New Madrid Floodway; however the text indicates that the data presented is applicable to only New Madrid Floodway lands impacted by the MRL feature of the project. Table B-5 of Appendix B provides a second example. The title reads “Expected Annual Acres” but should probably read “Expected Total Annual Acres Flooded”.

Generally, the document has the feel and appearance of being “overly revised” in that often the information provided in Appendix B of the 2013 DEIS appears to be an artifact of some previous analysis which may or may not be applicable to the current economic effort. Examples of this will be specified later in this review.

B. Failure to Establish Existing Conditions

Properly establishing the existing conditions is a fundamental first step to completing a meaningful economic analysis. Historical data should serve as the foundation for determining existing conditions which in turn then serve as the foundation for forecasting future conditions with and without project alternatives. Despite the contention that the study area is frequently flooded, evidence of historical flooded acres and actual flood related economic damages are not presented in the economic analysis.

On page 9 of the 2013 DEIS the following statement is made: “Flooding in the St. Johns Bayou Basin imposes a stiff toll in foregone and lost economic opportunity. Reliable estimates of crop damage due to flooding do not exist. Therefore, an economic model was used to quantify the economic impact of flooding on agricultural areas. The model is based on Current Normalized Prices. Additional information can be found in Appendix B.” The availability of historical flood damage data in the New Madrid Floodway study area is not addressed at all in the DEIS.

The collection and presentation of this historic data is required both to define the scope of the existing flooding problem and to validate any model estimates used in the analysis. Absent real data for model verification and validation the Corps economic analysis is best characterized as unfounded speculation. If this data is not extant given the long history of study of flooding in this area, then a natural question is: “Why has this data not been collected when it is critical to validating the economic analysis?” Again, the absence of this data renders the economic modeling as speculative and without any real foundation as there are no data points with which to compare the model produced estimates.

Similarly, examining Table B-1 in Appendix B, one discovers that the crop yield estimates are entirely contrived. It appears that this table displays some general ideas regarding what yields *might* be in the region above the 5-year flood plain and then subjectively reduces these yield estimates for application within the 5-year flood plain. Given the sensitivity of the economic benefit analysis to these crop yield estimates, this level of subjectivity is not sufficient. Any objective analysis must begin with real evidence of yields within the project area at different flood frequencies and elevations.

The production costs displayed in Table B-1 are also entirely unsupported by evidence. There is a very small difference between costs displayed for crop acreage within the 5-year floodplain and above the 5-

year floodplain but this difference in costs is unexplained in the text. Again, no evidence is provided that suggests these costs are based on the real expenses incurred by the farmers in this area. Further, at the very least, these costs should be disaggregated into the component costs of seed, fertilizer, labor, and other production costs. This would provide at least some limited basis for comparing costs between acreage in the 5-year floodplain and acreage outside.

The cropping patterns both in and above the 5-year flood plain are also estimated in Table B-1. The data on which these cropping patterns are estimated is neither provided nor referenced. The “intensification” benefit estimated later in the analysis is critically dependent on these cropping patterns so the fidelity of the cropping distribution is of paramount importance.

Normalized crop prices are the final set of external parameters displayed in Table B-1. Normalized crop prices are moving averages of recent historic crop prices and are designed to smooth the effects of short term price fluctuations. The accompanying text in Appendix B attributes these prices to the USDA Economic Research Service (ERS), however no specific citation is provided. For a comparison, reports from the ERS website (<http://www.ers.usda.gov/data-products/normalized-prices.aspx#.UmBu4Yko6pc>) were accessed and the following table of normalized prices compares the ERS web site data with the data presented in Table B-1 in Appendix B of the DEIS. Throughout this document, tables highlighted with a yellow background have been prepared and compiled by this author. Tables without a yellow background have been pulled from the body of the 2013 DEIS or Appendix B and were prepared by the Corps of Engineers.

Normalized Crop Prices Comparisons						
Crop	USDA Economic Research Service					
	FY 12 Table B-1	FY12 Missouri	FY12 National	FY11 National	FY10 National	FY09 National
Corn (bu)	\$3.38	\$4.09	\$4.01	\$3.37	\$3.07	\$2.74
Rice (cwt)	\$10.81	\$11.45	\$13.33	\$12.32	\$10.91	\$9.16
Cotton Lint (lb)	\$0.53	\$0.54	\$0.596	\$0.550	\$0.490	\$0.510
Cotton Seed (ton)	\$161.60	\$178.94	\$163.00	\$150.00	\$139.80	\$118.60
Soybeans (bu)	\$8.29	\$9.54	\$9.48	\$8.35	\$7.58	\$7.05
Wheat (bu)	\$4.22	\$4.52	\$5.62	\$5.16	\$4.87	\$4.19
Sorghum (cwt)	\$5.64	\$7.38	\$6.72	\$5.59	\$5.08	\$4.79

Normalized Crop Prices Comparison Table (source documents attached)

The normalized crop prices have a direct and significant impact on both the flood damage and intensification benefit estimates. The Crop Price Comparison Table above suggests that: 1) the normalized prices displayed in Table B-1 in Appendix B of the DEIS appear low relative to Missouri and national prices; 2) there is significant volatility even in these normalized prices; and 3) FY12 appears to be an above average year for most normalized crop prices.

Internally, Table B-1 computes some additional values such as the gross value of the crops (per acre) and provides some totals. It appears that, for the 5-year flood plain, the gross values of double crop soybeans are computed incorrectly. For double crop dryland soybeans the price is reported as \$8.29 per bushel with yield of 29.8 bushels per acre yielding a gross value of \$247.04 per acre. For double crop irrigated soybeans the price is \$8.29 per bushel with yield of 38.3 bushels per acre for a gross value of \$317.51 per acre. Table B-1 reports these values as \$246.63 and \$317.09, respectively. These computational errors are troubling in light of the lack of detail regarding the actual sources of data and the many undocumented computations performed throughout the analysis.

Similarly, in Table B-1 (and Tables B-2, B-3 and B-4 also in Appendix B) the price of “dryland” Sorghum is reported as \$5.64 while the price of “irrigated” sorghum is reported as \$5.04. Clearly one of these values is incorrect. This discrepancy is important in that crop prices have a direct and important impact of estimated economic benefits. The reader cannot determine which price is correct or even if the correct price was employed in the analyses.

C. Crop Yield and Production Cost Forecasts

As agriculture is the predominant and most likely economic activity to suffer flood related economic losses in the study area, crop prices, yields and production costs data and their forecasts are critically important to the analysis of the economic costs associated with flooding. Although crop prices are held constant throughout the study period at normalized 2012 price levels, crop yields and production costs are both forecast to increase through 2067 with crop yields increasing much more quickly than production costs. Consequently, each acre of crop land is forecast in Appendix B to produce more output in the future with a less than proportional increase in production costs thereby increasing flood related damages per acre over time for any given flood event.

Appendix B indicates that forecasting these increases in yields and production costs is accomplished by regressing historic annual ERS production and cost indices on calendar year to yield linear predictors of the indices. The equations reported in Appendix B are:

$y=0.0167348X-32.4349327$ for all crop yields; and

$y=0.0051037X-9.1882495$ for production inputs, where X represents the calendar year.

It should be noted that identical regression results were reported in the Economic Analysis Appendix of the 2002 Revised Supplemental Environmental Impact Statement (RSEIS), indicating that these regression equations apparently have not been updated with new data in at least a decade. Therefore, it appears that the most recent observations and trends (since 2002) in crop prices and production costs are not reflected in the forecast regression equations. This is a serious omission.

Using the base year of 2012 and the final forecast year of 2067 as X values in the crop yield regression equation generates index values 2.1559 and 1.2355 respectively; indicating a total yield growth over this time period of approximately 74% for all crops. Similarly, using 2012 and 2067 as X values in the production costs regression equation generates the values 1.3611 and 1.0804; implying a total production cost growth of approximately 26% for all crops.

Comparing the estimated yields per acre provided in Table B-1 (2012) with the forecasted yields per acre in table B-2 (2067) of Appendix B of the DEIS yields the following predicted yield growth rates in the 5-year to SPF Floodplain: Corn (62%), Rice (49%), Cotton (46%), Dryland Soybeans (45%), Irrigated Soybeans (46%), Wheat (53%), Double Crop Dryland Soybeans (46%), Double Crop Irrigated Soybeans (47%), Dryland Sorghum (56%) and Irrigated Sorghum (57%). The comparable estimates in the 5-year floodplain are slightly different yielding: Dryland Soybeans (47%), Double Crop Dryland Soybeans (44%), and Dryland Sorghum (55%). The other crops are either not shown for this area or show the same growth estimate (to the nearest percent). As these values vary by crop and are different from the crop yield growth rates implied by the crop yield regression equation result of 74% for all crops from 2012 through 2067, clearly, either a forecasting methodology other than that described in the Economics Appendix was actually employed in forecasting crop yields, or there are some serious computational issues in the forecasted yields employed in the economics analysis.

Similarly, comparing production costs forecasts between Table B-1 (2012) and Table B-2 (2067) of Appendix B yields an estimated 17% production costs increase across all crop categories. This growth rate in production costs is inconsistent with the result of a 26% increase over the period implied by the described regression methodology as well as appearing remarkably small. For comparison, the 2002 RSEIS projected a 60% growth in crop yields (applied equally to all crop categories) along with a projected 24% increase in production costs again applied equally across all crop categories.

It should be noted that all long term forecasts are fraught with uncertainty compounded, in this case, by significant uncertainty in the base year data. It should also be observed that the point forecasts made in support of the economic analysis represent just one of a wide range of potential futures. It is true that technological innovation has increased both the yields and (less so) the costs of producing these crops. However, increases in crop yields have historically exerted downward pressure on real crop prices which renders future crop yields and prices as likely negatively correlated random variables. This likely negative correlation has implications for conducting a meaningful risk analysis. These implications are addressed in the risk analysis section below.

D. Methodology – General

The establishment of the existing and without-project future conditions provides the foundation for estimating the potential economic benefits of project alternatives. This is true because the Corps employs a comparative statics economic analysis that compares economic conditions with each proposed project alternative in place to the economic conditions of the without project condition. The net difference in estimated economic conditions is the estimated contribution to the national economy of each alternative. Since all estimates of future economic conditions originate from existing economic conditions the critical need of establishing, verifying and validating existing conditions is obvious.

The categories of the estimated economic benefits described in Appendix B of the 2013 DEIS are: 1) crop damage reduction, 2) non-crop damage reduction, 3) intensification, and 4) streets and roads. In every instance, the DEIS and Economics Appendix fail to provide the needed detail and clarity of explanation essential to a constructive review and evaluation of the analyses underlying the computation of the benefit estimates.

Further, the Economics Appendix, which should provide detailed support for the economic analysis of all alternatives, focuses nearly entirely on just one (Alternative 3.1) of the many alternatives under consideration. However, it fails to convey the details of even that single alternative.

Reliance is placed on a barely explained model, the Corps’ “Crop Flood Damage Analysis” (CFDA) model, to provide the agricultural crop damage reduction benefit estimates. Volume 3 of the 2013 DEIS provides certification reviews of many of the models used in preparation of the DEIS. The certification review of the CFDA is notably absent. The main body of the DEIS indicates in Figure S.1 (page V) that economic models should be part of the review and certification process. The absence of documentation suggests that this review and certification of economic models may not have occurred.

Beyond the lack of explanation of the actual “inner workings” of the CFDA model itself, the inputs used to drive the model estimations are not provided in the body of the DEIS or the Economics Appendix. Therefore, a reviewer cannot even validate the inputs used by the “black box” CFDA mode to produce crop flood damage estimates.

All of the estimated economic benefit categories ultimately derive from the reduction of flood risk. For that reason the economic analysis should have begun with a detailed identification and evaluation of the extent of without-project flooding. This should have been followed by an evaluation of the flooding risk under each distinct alternative. The DEIS and Economics Appendix did not accomplish this.

In order to facilitate this review, an estimate of expected annual flooding is provided here. This estimate is derived from information included in the main body of the 2013 DEIS and also in Appendix D (History).

In the main body of the 2013 DEIS (page 6) the following flood frequency chart is provided

Table 1.1. Existing flood frequencies and associated inundated acres, St. Johns Bayou Basin and New Madrid Floodway.

Event	St. Johns Bayou		New Madrid Floodway		Total Acres
	Elevation	Acres	Elevation	Acres	
1.01 year	281.6	753	279.3	404	1,157
2-year	291.0	11,904	292.1	33,391	45,295
5-year	294.1	20,407	296.6	58,990	79,397
10-year	295.6	26,972	298.7	70,749	97,721
20-year	296.9	38,433	300.5	81,758	120,191
50-year	298.4	43,483	302.5	93,396	136,879

An entirely different Flood Frequency Chart is also found in Table 3 of Appendix D – Historic Conditions of the DEIS (Appendix D-Part 2-page 15). The indicated source for this table is: U.S. Army Corps of Engineers, 2009a, Consolidated Environmental Impact Statement for the St. John’s Bayou-New Madrid Floodway Project, U.S. Army Corps of Engineers, Memphis District, Memphis, TN.

Table 3 in Appendix D

Event (year)	SJBB Acres	NMF Acres	Total Acres
2	10,056	17,316	27,372
5	30,032	35,381	65,413
10	34,155	53,519	87,674
25	40,073	70,108	110,181
30	55,000	75,078	130,078

It is interesting to note the significant differences between these two tables, especially for the 2 and 5-year events. The number of acres flooded in the 2-year event predicted by Table 3 (Appendix D) is approximately 40% less than that predicted by Table 1.1 (2013 DEIS). The number of acres flooded in the 5-year event predicted by Table 3 (Appendix D) is more than 17% less than that predicted by Table 1.1 (2013 DEIS).

This reviewer estimated the mean annual flooded acres based both on Table 1.1 (2013 DEIS) and on Table 3 (Appendix D). Because the tables do not provide information above the 50-year and 30-year events, respectively, there is some uncertainty regarding the impact of floods exceeding these levels. The Microsoft Excel Spreadsheet used to perform the estimations is provided as an attachment to this review.

Without-Project Summary (Based on DEIS Table 1.1) Estimated Annual Mean Total Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	11,761.6	33,108.4	44,870.0
above 5 to 50 year floodplain	1,862.8	2,755.3	4,618.1
Above 50 year floodplain (approximate)	869.7	1,867.9	2,737.6
Total	14,494.1	37,731.6	52,225.7

Without-Project Summary (Based on Appendix D, Table 3) Estimated Annual Mean Total Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	13,756.8	18,607.2	32,364.0
above 5 to 30 year floodplain	1,479.8	3,718.9	5,198.7
Above 30 year floodplain Approximate	1,833.3	2,502.6	4,335.9
Total	17,069.9	24,828.7	41,898.6

The above tables estimate the total expected annual flooding, but the crop acres flooded are of particular interest. The 2013 DEIS states (pages 8 & 9) that, for the SJBB, the percentage of agricultural land in the 5-year and 50-year flood plains are 70% and 78%, respectively. Similarly the DEIS states (pages 12 & 13) the analogous percentages as 80% and 83% for the NMF, respectively. Using these percentages and assuming 90% cropland coverage above the 50-year threshold, the following estimation of annual mean crop flooding resulted:

Without-Project Summary (Based on DEIS Table 1.1) Estimated Annual Mean Crop Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	8,233.1	26,486.7	34,719.8
above 5 up to 50 year floodplain	2,393.9	3,280.1	5,674.0
Above 50 year floodplain Approximate	782.7	1,681.1	2,463.8
Total	11,409.7	31,448.0	42,857.7

Because Table 3 shows flood frequency only to the 30-year event, the 50-year floodplain percentage of agricultural land was applied to all flooding above the 30 year event. The following estimate was computed:

Without-Project Summary (Based on Appendix D, Table 3) Estimated Annual Mean Crop Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	9,629.7	14,885.8	24,515.5
above 5 up to 30 year floodplain	2,254.8	3,644.9	5,899.7
Above 30 year floodplain Approximate	1,430.0	2,077.2	3,902.3
Total	13,534.5	20,783.0	34,317.5

Note that the cropland flooding implied by Table 1.1 (2013 DEIS) exceeds that implied by Table 3 (appendix D) by almost 25%. Because of limited detail provided in the 2013 DEIS, estimating similar figures for the “with-project” conditions is not possible. However, Table 2.11 of the 2013 DEIS (page 50) provides the reduction in flooded acres under the various alternatives. The reductions estimates in the table are reproduced below:

Reduction in Flood Acres (reported in DEIS Table 2.11)							
	Alt. 2.1	Alt. 2.2	Alt. 2.3	Alt. 3.1	Alt. 3.2	Alt. 4.1	Alt. 4.2
All Land	3,085	52,108	55,193	46,248	48,145	41,883	41,883
Agricultural Land	2,646	44,372	47,018	40,597	42,105	37,030	23,690

Note that, for most of the alternatives, the flood reduction appears to exceed this reviewer's estimate of the total expected annual flooding of 41,898.6 acres computed from the Historic Conditions (Appendix D Table 3). In particular, the 2013 DEIS reports that Alternative 3.1 reduces total flooding by 46,248 acres while reducing agricultural acre flooding by 40,597. These values will be revisited later in this review.

E. Estimation of Crop Damages

Agriculture is the predominant and most likely economic activity to suffer flood related economic losses in the study area. This crop damage reduction estimate accounts for approximately 38% of the total Alternative 3.1 combined SJBB & NMF estimated economic benefits.

The economic benefit estimation associated with the reduction of crop damage losses is accomplished using the Corps' Crop Flood Damage Analysis (CFDA) model. As stated previously, the model inputs and methodology are not made available for review. Therefore, only the reported results can be examined.

In Table B-7 of the economics appendix the (per acre) crop damage rates for both the current and future conditions are reported. This is done for both for the without-project and with project (Alt 3.1) alternatives. For reference the table is reproduced below:

Table B-7 (Crop Damage Rates)

Item		Without Project		Alternative 3.1	
		0-5 year	5 yr-SPF	0-5 year	5 yr-SPF
Headwater					
	Present Condition	64.34	25.45	64.34	25.45
	Future Condition	112.65	53.37	112.65	53.37
Backwater					
	St. Johns Basin				
	Present Condition	64.34	25.45	37.86	20.71
	Future Condition	112.65	53.37	65.98	40.60
New Madrid Floodway Basin					
	MRL Closure				
	Present Condition	38.49	9.25	45.29	0
	Future Condition	69.57	18.04	80.88	0
	Pump				
	Present Condition	72.4	28.90	14.68	28.90
	Future Condition	125.14	61.50	23.68	61.50

Note that the damages are disaggregated by the type of flooding event (headwater or backwater) and by the specific project area (SJBB or NMF). The NMF area is further disaggregated by the region protected by the closure and that protected by the pumping station. Finally, damages within the 5-year floodplain are distinguished from those above the 5-year floodplain.

The lowest damage estimate is \$9.25 per acre for without-project damage occurring under present conditions from backwater floods above the 5-year flood plain in the NMF area to be protected by the MRL closure. The highest reported damage estimate is \$125.14 per acre for damage occurring within the 5-year flood plain under without-project future conditions in the NMF area to be protected by the pumping station. The Table below, compiled for this review, presents the future damage estimates relative to the present damage estimates in terms of percentage increases.

Present to Future Estimated Flood Damage Percentage Increases				
Item	Without Project		Alternative 3.1	
	0-5 year	5 yr.-SPF	0-5 year	5 yr.-SPF
Headwater				
Percentage Future Increase	75.09%	109.71%	75.09%	109.71%
Backwater				
St. Johns Basin				
Percentage Future Increase	75.09%	109.71%	74.27%	96.04%
New Madrid Floodway Basin				
MRL Closure				
Percentage Future Increase	80.75%	95.03%	78.58%	
Pump				
Percentage Future Increase	72.85%	112.80%	61.31%	112.80%

Note that these increases range from about 73% to about 113%. These increases in future flood damage estimates cannot be reconciled with the forecasted yield and cost increases in Appendix B.

The second important factor in estimating crop damage is the estimate of acres flooded. These are reported in Appendix B, Table B-5 reproduced below for convenience. Note that the terms “Present” in this table indicates the current (2012) agricultural acreage while the “Future” (2067) represents a condition where some land is removed from agricultural production.

Under present conditions the without project condition in this table implies an expected annual flooding of 121,207 acres. Of this total, 116,525 acres are attributed to flooding within the 5-year floodplain. Referring back to Table 1.1 of the DEIS this expected annual flooding estimate significantly exceeds the approximately 79,000 acres even in the 5-year floodplain. Further note that the estimates prepared above based on the flood frequency tables indicate expected annual without-project flooding cropland in the 5-year floodplain to be between approximately 25,000 and 35,000 acres.

Table B-5
Expected Annual Acres
Oct 2012 Price Levels

Item	Without Project		Alternative 3.1		Reduction	
	0-5 year	5 yr-SPF	0-5 year	5 yr-SPF	0-5 year	5 yr-SPF
Headwater						
St. Johns Bayou	5,418	52	818	0	4,600	52
St. James Ditch	7,538	168	246	0	7,292	168
Birds Point Levee Ditch	8,392	64	207	0	8,185	64
Backwater						
St. Johns Basin						
Present	12,504	1,714	7,417	264	5,087	1,450
Future	10,792	1,659	6,472	256	4,320	1,403
New Madrid Floodway Basin						
MRL Closure						
Present	68,382	1,318	15,657	0	52,725	1,318
Future	66,612	1,318	14,408	0	52,204	1,318
Pump						
Present	14,291	1,366	9,510	16	4,781	1,350
Future	13,052	1,356	8,404	16	4,648	1,340

Finally, a similar table from the 2002 RSEIS (Table 5) shows the expected annual acres flooded in the without project condition as 57,370 acres, a little less than one half of the estimate computed from the data in Table B-5 of Appendix B of the 2013 DEIS. Table 5 of the 2002 REIS also shows an expected 16,386 (reduction of 40,984) acres flooded in the with-project (Alternative 2) condition. This is further evidence of the inconsistency of these calculations.

It appears that the annual expected flooding predicted in the 5-year floodplain is overestimated by at least a factor of 3. The expected annual flooding indicated by Table B-5 above the 5-year floodplain is 4,682 acres. This actually appears to be a bit low based on the flood frequency data.

The present-condition expected annual flooding under Alternative 3.1 in Table B-5 of Appendix B is estimated by the Corps to be 33,855 acres in the 5-year flood plain and 280 acres above the 5-year flood plain. Note that the Corps' reported expected acreage flooded within the 5-year floodplain in this with-project condition is comparable to what should be expected in the without project condition.

The reduction in expected total annual flooding afforded by Alternative 3.1 (with existing conditions) is therefore equal to 121,207 acres (the without project expected total annual flooding) less the expected total annual flooding with Alternative 3.1 in place (equal to 33,855 acres in the 5-year flood plain plus 280 acres above the 5-year flood plain), which yields an expected annual reduction in total flooding of

some 87,072 acres. Note the discrepancy between this number and the 40,597 acre reduction reported in Table 2.11 of the 2013 DEIS. Further note that the reduction in flooding estimated in the 2002 RSEIS, 40,984 for Alternative 2 is close to the 40,597 acre number in Table 2.11 of the 2013 DEIS. The future conditions show some (small) reduction in the flooding based on land being removed from agricultural production.

The estimated crop damages and reduction benefits are displayed in Table B-8 of Appendix B for selected years. The damages appear to be computed, for a given year, as follows:

1) The crop damage factors are computed for the year by interpolating between the present (2012) damage and future (2067) damage factors (Table B-7). For example in the year 2027 the damage factor would be:

$$DF = PDF + [(2027-2012)/(2067-2012)]*(FDF - PDF)$$

Where DF is the damage factor for the selected year, PDF is the present damage factor (2012), and FDF is the future damage factor (2067).

For backwater floods in the SJBB 5-year floodplain the PDF=\$64.34 and the FDF=\$112.65, so the damage factor for 2027 is:

$$\$64.34 + [(2027-2012)/(2067-2012)]*(112.65-64.34) = \$64.34 + (15/55)*(\$48.31) = \$77.52$$

2) The expected acres flooded are computed for each item and category. For some items, such as headwater flooding of the St. Johns Bayou, the expected flooding is constant throughout the period of analysis (Table B-5). For those items where separate estimates were made for present and future conditions, interpolation is used to find the expectation for any given year. For example, for SJBB backwater flooding in the 5 year floodplain the present expectation of flooding is reported as 12,504 acres and the future expectation is reported as 10,792 acres. Hence the expected flooding in 2027 is computed as:

$$12504 + [(2027-2012)/(2067-2012)]*(10,792 - 12,504) \approx 12,037 \text{ acres.}$$

3) The flood damage for the year, item, and category is found by multiplication. So the expected flood damage for SJB backwater flooding in 2027 is estimated as:

$$(\$77.52)*12037 = \$933,115$$

4) Table B-8 in Appendix B displays with and without-project estimated damages associated with the MRL closure and the difference between these damage estimates (crop damage reduction). However, it displays all the other with and without-project damage estimates under the heading "First Phase Features".

5) The yearly damages and damage reductions are discounted at 4% to the year 2017, and then amortized at 4% over 50 years.

6) A reduction was made to the crop damage reduction benefit (First Phase Features) to account for the overlap of headwater and backwater flooding.

The mathematics described above appear to have been executed correctly, however because the estimated benefits are directly proportional to the expected flooding, the apparent over-estimation of flooding will produce a corresponding over-estimation of the crop damage reduction benefits. Further, even if the quantity of flooding were not an issue, the failure to definitively establish the “existing conditions” together with the uncertainty in forecasting the future condition would make it difficult to be confident in these estimations.

This crop damage reduction estimate accounts for approximately 38% of the total Alternative 3.1 combined SJBB & NMF estimated project benefits.

F. Agricultural Non-Crop Benefits

The agricultural non-crop benefits are the economic benefits that accrue to non-crop related production items in agricultural areas due to flood damage prevention. As agricultural areas predominate in the study area this economic benefit category is important to determining the economic effects of potential projects. This benefit category represents approximately 14% of the total estimated economic benefits for Alternative 3.1.

Appendix B bases its agricultural non-crop damage estimates on a 1994 study that examined flooding in the lower Yazoo and Mississippi River Delta areas. The applicability of those now nearly twenty years old results to the economic analysis of flood protection in the SJBB and NMF is, at best, tenuous. Further, the 1994 study which is entitled “Agricultural Non-Crop Flood Damage: Mississippi Delta, Mississippi” is not made available in the 2013 DEIS nor does it appear to be available on the web.

Since this report forms the foundation for estimating the non-crop benefits it should be subject to the same standard of review and certification as any other model or data used in the 2013 DEIS. There is no evidence presented in the DEIS indicating that the 1994 report was ever reviewed or certified.

Also Appendix B states that the estimated non-crop flood damages were updated from the 1994 report values to 2012 price levels. It neglects to inform the reader of the methodology used to update the prices. Was this based on the producer price index, consumer price index or some other inflation rate index? The original report damage estimate should be included along with the factor used to update this parameter.

The economic analysis adopts a 2012 non-crop damage estimate of \$24.69 per flooded acre stating that, “...it was felt prudent to err to the conservative side”. This estimate is entirely speculative, may or may not be “conservative” but is clearly not supported by any real research or data applicable to the SJBB and NMF study area. Again, with the historic frequency of flooding in the SJBB and NMF area why has there been no effort to collect real damage data which could be used to appropriately estimate this parameter?

It is further explained in Appendix B that the non-crop damage factor was forecast to 2067 using the same methodology as used for forecasting crop production costs. The result was an estimate of \$28.80 in 2067. While numerically the forecast to \$28.80 is consistent with the forecast of crop production costs (approximately 17%), it is entirely without basis. The increase in production costs *should* represent the cost of adopting the new technologies (i.e. genetically modified seed) that drive the increased yields. Costs imposed by non-crop damages do not represent a new farming technology and hence should, like crop prices, be held constant at their 2012 levels in this analysis.

The estimated non-crop damage rates per acre are applied to the expectation of flooded agricultural acres displayed in Table B-5. This is problematic since, as demonstrated previously, these estimates of flooded acreage appear to be grossly overstated.

Also note that the benefit stream for the “First Phase Features” without-project condition in Table B-10 shows a mathematically incorrect average annual equivalent. The stated value is “1,326,000”; the correct figure is “1,632,000”. This error is extended into the calculation of total average annual benefits.

The estimated average annual non-crop damage benefit claimed for the combined SJBB & NMF for Alternative 3.1 is \$2,258,000. This represents approximately 14% of the total estimated benefits for this alternative. Simply applying the 40,597 acre reduction in flooding claimed in DEIS Table 2.11 to the \$24.69 estimate of non-crop damages yields \$1,002,340. Given that estimated flooding is reduced over time due to conversion of cropland it seems that, if computed correctly, the average annual non-crop damage reduction benefits should not exceed \$1,000,000.

Beyond the concerns with the benefit estimation, there is also the suspicion that these non-crop damage reduction benefits may overlap either the benefit estimation for reduction of crop damages or (to a lesser extent) the benefit estimated for reduction of street and road repairs. The production cost estimates used in the CFDA model and the operation of the model itself are never explained in Appendix B (or elsewhere in the DEIS), so it is not possible to determine if non-crop damages factor into the production costs used by the CFDA model. It is easy to imagine that the non-crop damages could potentially be accounted for in the CFDA model. It should be noted that the economic analysis provided with the 2002 RSEIS did not include an estimate of non-crop flood damage reductions, even though this is a standard category of flood project benefits.

Finally, Alternative 3.1 allows for winter and early spring flooding in the NMF. Because of the issues with the flooding estimates, it is not clear if any non-crop damages associated with these controlled flooding events are deducted from the non-crop agricultural benefit estimation.

G. Intensification Benefits

The Corps of Engineers uses the term “intensification benefit” to identify the economic benefits associated with reduced flood risks that are not reductions of existing flood damages or future flood damages to existing economic activities. Therefore, this benefit category is designed to capture the beneficial economic effects of more valuable uses of existing flooded areas made possible by reductions in flood risk. In this study, these intensification benefits are derived from the potentially more productive use of agricultural land when flood risks are reduced. Crop yields can be increased or more

valuable crops can be produced. This can be an important category of economic benefits. The estimated intensification benefits account for approximately 23% of the estimated project (Alternative 3.1) economic benefits.

The process described for estimating the intensification benefits involves first identifying the areas subject to intensification. The analysis assumes that the (agricultural) acres within the 5-year floodplain in the without-project condition reduced by the acreage still in the 5-year floodplain in the with-project condition are those acreages subject to intensification. These acres are displayed in Table B-11 of Appendix B of the DEIS and are reproduced below (this reviewer has added the “Totals” rows).

Note that the total present (crop land) acreage implied by Table B-11 exceeds the total acreage (Table 1.1 – 79,397) in the 5-year floodplain. The land claimed to be subject to intensification (69,600) constitutes approximately 88% of the total land, which is very likely more than the total cropland in the 5-year floodplain. The acreage in the five-year floodplain after implementation of Alternative 3.1 also looks high, but the absence of detail does not allow for this determination.

The apparent assumption made to determine per acre benefits of intensification is that the acres which, due to the project, are removed from the 5-year floodplain will become productively equivalent to lands previously above the 5-year floodplain. The difference in the net productive values of these lands constitutes the estimation of the intensification benefit (per acre). This benefit is then reduced to account for the increased damage due to any residual flooding on these lands.

Table B-11 Area Subject to Intensification

Item	Without-Project	Alternative 3.1	Area Intensified
Headwater			
St. Johns Bayou	3,248	1,074	2,174
St. James Ditch	7,284	330	6,954
Birds Point Levee Ditch	5,932	0	5,932
Backwater			
St. Johns Basin			
Present	14,527	11,286	3,241
Future	12,912	9,895	3,017
New Madrid Floodway Basin			
MRL Closure			
Present	61,518	18,034	43,484
Future	60,664	17,370	43,294
Pump			
Present	18,034	10,219	7,815
Future	17,370	9,590	7,780
Totals			
Present	110,543	40,943	69,600
Future	107,410	38,259	69,151

The Economic Appendix states that this increase in net productive value was derived from the information presented in Tables B-3 (2012) and B-4 (2067), but does not inform the reader of these values or explain how they were derived.

Table B-3 purports to show the crop budgeting data that would be applicable “with the MRL features” in the SJBB and NMF study area for lands already protected from backwater flooding. In this table the yields, costs, and crop distributions presented for the 0-5 year floodplain now mirror those previously presented in table B-1 for the 5 year-SPF floodplain.

The changes in yields, costs, and distributions displayed in Table B-3 for the 5 year-SPF floodplain are completely undocumented and appear to be arbitrary and contrived. In particular the land distribution data presented in this table is identical to that found in the 2002 RSEIS (Table B-3), however, in that case the data purported to represent the crop distribution in the 3 year-SPF floodplain.

Table B-4 in Appendix B of the 2013 DEIS is a projection of Table B-3 data to the year 2067. Since the (per acre) increases in net productivity are not reported, this reviewer attempted to infer their values from the intensification benefits claimed in Tables B-11, B-12 and B-13. For the year 2067, the increased residual flood damages estimates from intensification presented in Table B-12 were added to the claimed intensification benefits presented in Table B-13. The resulting sum (which should represent the total intensification for all intensified acres) was then divided by the estimated number of acres subject to intensification presented in Table B-11. This procedure yielded the following estimates of the implied intensification values per intensified acre:

Year 2067 Per Acre		
Implied Intensification		
MRL	1st Phase	Overall
Acres	Acres	Acres
\$120.70	\$48.63	\$93.75

From the supplied information in Appendix B it is not clear how these intensification values per acre were derived by the Corps, nor is it documented in the appendix how and why the values differ between the two project areas. Given the lack of provided computational details in the report and the absence of historical cropping data it is impossible to ascertain if these intensification estimates per intensified acre are accurate or even reasonable.

Beyond the apparent problems with the acreage estimates and the calculations, there are four serious concerns with the methodology used to estimate these intensification benefits. First, the choice of the 5-year floodplain as the threshold for application of intensification is completely arbitrary. In fact, the 2002 RSEIS chose the 3-year floodplain as the threshold. A more appropriate analysis would not adopt an all-or-nothing approach to the estimation of the intensification benefits, but would instead recognize that crop production decisions are continuously dependent on flood risks.

Second, the estimation of the intensification benefit is extremely sensitive to the crop yield and farm budget information. To illustrate the sensitivity, consider the following hypothetical example.

HYPOTHETICAL EXAMPLE			
	Before Intensification	After Intensification	Intensification Benefit
Gross Production Value	\$350.00	\$400.00	
Production Cost	\$290.00	\$300.00	
Net Value	\$60.00	\$100.00	\$40.00

Now suppose, for example, that the gross production (yields) were underestimated by just 1% in the “before” case and costs were overestimated by just 1% in the “before” case. This yields the following:

HYPOTHETICAL EXAMPLE			
	Before Intensification	After Intensification	Intensification Benefit
Gross Production Value	\$353.50	\$400.00	
Production Cost	\$287.10	\$300.00	
Net Value	\$66.40	\$100.00	\$33.60

Note that the intensification benefit is reduced by 16% in response to a 1% mis-estimation of crop yields and budgets in the illustration. This demonstrates that the estimation of the intensification benefit is extremely sensitive to the crop yields and farm budgeting information. As detailed earlier in this review, Appendix B does not demonstrate an accurate and precise knowledge of these two critical factors in the study area rendering the Corps’ intensification benefit estimates fragile and completely speculative.

Third, the intensification benefit is assumed to occur instantaneously with the implementation of the project. To the extent that the intensification involves farmers changing their long standing practices, it would seem more appropriate to phase in these intensification practices over a period of time.

Finally, even in the without-project future circumstance changes will be made in farming practices due to changing future economic conditions. If the yield and cost forecasts made in the analysis were in fact realized then there would be some natural shift to crops offering a greater net return in the without-project condition. Since the analysis does not explore this eventuality, some portion of the estimated intensification benefit may be invalid and should have been more appropriately incorporated and estimated in the crop-damage reduction benefit category.

H. Land Value Approach

The reduction of crop damage and non-crop damages together with the intensification account for approximately 76% of the combined SJBB and NMF estimated project economic benefit (Alternative 3.1). These types of benefits are very likely to be observable in the differences in values of agricultural land in the study area exposed to differing degrees of flood risk. Therefore, these estimations of flood reduction benefits could and should have been validated by performing an analysis of cropland price

differences in the study area by location in the floodplain, but this was not done. Validation through an analysis of cropland prices is an acceptable and recognized Corps of Engineers methodology (Corps of Engineers ER1105-2-100, 22 April, 2000, page E-119). The lack of historical damages and/or accurate farm budget information does not impact this type of analysis and would provide a reality check for the estimated crop damage, non-crop damage and intensification economic benefits.

I. Streets and Roads Benefits

An average annual benefit of \$3,746,000 (Alternative 3.1) is claimed under the Streets and Roads economic benefit category. This benefit category is intended to measure the reduction in street and road operation, maintenance and repair costs associated with reduced flooding in the project area afforded by a project. This category accounts for 24% of the combined SJBB & NMF estimated project benefits (alternative 3.1).

In particular an average annual savings of \$3,439,000 is claimed for avoiding expensive improvements to Interstate 55 that would be “required” in the future in the without project condition. This represents approximately 92% of the asserted street and road benefits and 22% of the combined SJBB & NMF estimated project benefits (Alternative 3.1).

Despite the large impact on the total benefit estimation, the protection of Interstate 55 (I-55) receives scant attention in Appendix B. Only one paragraph is allotted to this issue. Several problems are apparent and need to be addressed.

The cost estimate for raising I-55 in the without project future condition is the estimated benefit, as it is a cost that is assumed avoided in the with-project conditions. The cost estimate itself was prepared by the COE Memphis District. It is not clear that this estimate was prepared at the request of the Missouri Department of Transportation (MDOT). The degree, if any, of coordination with MDOT is not discussed. It is not known if MDOT endorses the cost estimate or if MDOT endorses the project (Alternative 3.1) as a solution to the flooding issues on I-55.

Finally, is the issue regarding whether raising I-55 to avoid flooding in the absence of the Corps’ project is itself a justified project. Appendix B of the 2013 DEIS offers no economic based rationale to justify raising I-55 in the future without project conditions of this project.

The remaining street and road benefits are small (approximately two percent of total benefits) and asserted without any underlying analysis. Together with the I-55 cost avoidance benefits, the total estimated streets and roads benefit accounts for approximately 24% of the estimated project (Alternative 3.1) benefits.

J. Project Costs

A detailed examination of the project construction and environmental costs are beyond the scope of this review. However, a couple of comments are in order. First, the “economic” cost of the project excludes \$22,443,000 of “financial” project costs and is based on an alleged difference between the financial cost of acquiring land for the project and the real economic cost of the land. While it is true that financial costs and economic costs can be different when the financial costs do not represent the true

opportunity costs of the foregone use of the land, the evidence supporting this claim in this case is insufficient. Second, the estimations of environmental mitigation costs in the DEIS are poorly presented and difficult to understand.

K. Risk Analyses

There is always uncertainty present when conducting an economic analysis of Corps of Engineers flood damage reduction projects. This uncertainty is in large part a consequence of the need to forecast the with and without project economic conditions many years into the future (50 years or more) over the productive life of a flood control project. Identifying the sources of uncertainty and ranges of possible values for important uncertain parameters assists in making a reasoned evaluation of alternatives by facilitating an examination of the relationship of possible values of these important parameters to potential economic outcomes. To analyze the sources of uncertainty present in its economic analysis the Corps devotes two sections of Appendix B of the 2013 DEIS to what is termed “risk analysis” where they examine uncertain variables whose realization possibilities can be quantified with probability distributions. Additionally there is a section in Appendix B entitled “Sensitivity Analysis” that further explores uncertainties in their analysis for parameters that aren’t readily quantified through probability distributions. The two risk analysis sections pertain to Flood Damage Reduction benefits and Intensification benefits, respectively.

The risk analysis would be improved by combining these two sections into a single risk and uncertainty section. Especially since much that is presented in the second risk analysis section is redundant. Also, related to the presentation, Table B-9 in Appendix B is intended to show the risk analysis results for Alternative 3.1 but in fact it displays results for Alternative 2. The incorrect values from this table are used in the write-up and are confusing, since the values cannot be reconciled with the referenced alternative.

For both the flood damage reduction and the intensification the risk analysis was conducted using the @Risk Excel add-in. This add-in allows the user to specify parameters as probability distributions rather than specific point values.

As with the other economic models, it is not clear if this model was ever reviewed and/or certified. The explanation of the model is perfunctory, and the model itself is not supplied for the readers review.

The presentation in Appendix B shows that for every uncertain parameter a normal distribution was selected. The previously determined point-estimate is used as the mean of the normal distribution. No rationale is provided as to why normal distributions were selected. Further, for most of the parameters the choice of the normal distribution is clearly inappropriate. For example production costs are bounded from below; significantly lower costs are much less likely than significantly higher costs and a symmetric normal distribution is unlikely to accurately represent the probabilities of realized costs.

The standard deviations selected to scale the normal distributions are clearly arbitrary and appear artificially low. For example the standard deviation selected for crop prices is 15%. Examining the data in the Normalized Crop Price Comparison Table above clearly indicates that the actual volatility of crop prices is likely much more than that represented by a normal distribution with a standard deviation of

15%. Most troubling is that, for most of the parameters involved, data is readily available to construct reasonably accurate probability distributions; but apparently this was not done.

A further concern is that each parameter is considered to be independent of the values of all other parameters. They clearly are not. For example, high crop yields in a given year tend to correlate with lower real crop prices making these two variable values interdependent. Crop yields are likely positively correlated with productions costs. Assuming independence of clearly dependent parameters distorts the probabilities of jointly distributed parameter outcomes rendering the evaluation of each variables contribution to uncertainty in project outcomes to be distorted as well.

Because 1) there is a linear (or near linear) relationship between most of the assumed independent parameters and the estimated economic benefit; and 2) the normal distribution is symmetric around the mean; the variation of these parameters will not (significantly) impact the mean benefit estimate. At best it will just demonstrate the uncertainty in the estimated benefits around its mean value. Unfortunately, because arbitrary values were used for the standard deviation it fails to accomplish even this.

A notable exception to a near linear relationship between a variable and project outcomes is the stage-frequency relationship. Because the stage-frequency curve has a very non-linear relationship to the acreage flooded and, therefore, the estimated benefits, the variation of this parameter actually does significantly impact the mean estimate of benefits.

A comprehensive risk analysis is essential to a quality study. However the risk analysis described in Appendix B does a disservice by leading the reader to believe there is less uncertainty in the project benefit estimates than most likely actually exists.

The sensitivity analysis presented in Appendix B addresses discount rates and carbon sequestration. One interesting artifact of the sensitivity analysis can be observed in Table B-24 of Appendix B. For most projects increasing the discount rate leads to higher estimated costs and lower estimated average annual benefits. In this particular case increases in the discount rate actually corresponded to higher estimated benefits for the SJBB. Apparently this is due to the large contribution of the I-55 without project future condition cost avoidance benefit to the overall SJBB benefit estimate.

As part of the sensitivity analysis project benefits should be estimated holding the input parameters at their present levels. This would help the reader understand the degree to which the forecasts impact the project benefits.

Finally, the risk and sensitivity analyses presented in Appendix B are most notable for what is not addressed. Risk analysis was performed for only two of the four benefit categories. Cost uncertainties were not addressed at all, even though experience indicates that Corps cost overruns are highly likely events.

Other issues that should have been, but were not, addressed in the risk analysis are:

- 1) What are the likelihoods and consequences of the project not performing as intended? For example if one of the pumps failed, what would happen and what are the economic consequence?
- 2) What are the economic consequences of a massive flood event, where the NMF would need to be used to provide flood relief?
- 3) What are the economic consequences of a massive flood event if the NMF is not used?

L. Miscellany

The 2013 DEIS (main) states:

“Benefits and impacts of each alternative are summarized in Table 2.11. The relationship of each alternative to environmental protection statutes or other environmental requirements is summarized in Table 2.12. Alternative 3.1 is the NED plan. Thus, it was identified as the tentatively selected plan. Detailed information regarding project benefits, impacts, mitigation, monitoring, and adaptive management can be found in Sections 3-7.” (page 49)

In Appendix B (Economics) under the heading “NED PLAN” it states:

“A true NED plan was not identified in that all components of the plans were not optimized or sized.”

This is a deficiency. The plans should have been optimized and an NED plan identified.

IV. Independent External Peer Review

Leaving aside the question as to whether a review that is sponsored by the performing agency can truly be considered independent, the external reviewer of the economic analysis made several salient comments. Regretfully many do not seem to have been addressed in the 2013 DEIS economic analysis.

Here are some selected examples:

“Baseline agricultural economic conditions are not adequately supported with evidence, nor are the predicted future economic benefits associated with the project.” (Part 2 (Appendix A) – Page A-4)

“The majority of claimed net benefits for the project pertain to changes in agricultural yields that correspond to lower flood risks, but the DEIS does not include the justification to corroborate these findings.” (Part 4 – Page 3)

“The project need, which is based on economic losses due to agricultural flood damage, is not quantified.” (Part 4 – Page 5)

More examples may be found in Volume 3 of the 2013 DEIS. It serves no constructive purpose to have expert review if the observations are simply ignored.

V. Conclusions & Recommendations

The economic analysis in the DEIS lacks the scope, data, detail, quality of execution and quality of presentation required to support such an important and controversial public policy decision involving

the commitment of between \$58 and \$180 million of scarce resources (depending on the alternative implemented) with such potentially large environmental consequences. The analysis relies on arbitrary assumptions. Important specific and significant project-area supporting data is lacking. In many instances the descriptions of the analytical methodologies employed are insufficient to determine what was actually done, in other instances no descriptions of employed methodologies are provided at all, in still other instances, the employed methodologies appear questionable at best. Further, the economic analysis is fraught with both demonstrable and apparent errors. The results of the 2013 DEIS Economic Analysis should not be used as a basis for any public policy decision.

At the very least, for the DEIS to be useful in informing a public policy decision of this magnitude, I recommend three improvements to the presented analysis: (1) accurate data truly representing the existing conditions at various flood frequencies and elevations in the project area must be obtained and verified; (2) using that data, the errors in the current execution of the economic analysis must be acknowledged and corrected with updated and certified models; and (3), finally, the real levels of uncertainty present in the analysis and results must be identified, acknowledged and reported.

Attachment 1
USDA Economic Research Service 2012 Normalized Prices

Table 1—Normalized Price Estimates, National Level¹

Commodity	2007	2008	2009	2010	2011
Wheat, all types (bushels)	\$3.31	\$3.61	\$4.19	\$4.87	\$5.16
Rye (bushels)	3.13	3.22	3.56	4.23	4.58
Rice (cwt)	6.36	7.50	9.16	10.91	12.32
Corn for grain (bushels)	2.15	2.37	2.74	3.07	3.37
Oats (bushels)	1.60	1.65	1.82	2.15	2.26
Barley (bushels)	2.56	2.68	2.94	3.45	3.89
Sorghum grain (cwt)	3.68	4.16	4.79	5.08	5.59
Hay, all types, baled (tons)	92.92	95.62	102.74	116.04	119.24
Dry beans (cwt)	20.36	20.36	22.70	25.94	26.80
Sugarbeets (tons)	40.20	41.12	41.60	42.94	45.64
Sugarcane for sugar (tons)	28.72	29.00	29.20	29.20	30.50
Cotton, lint, upland (pounds)	0.50	0.45	0.51	0.49	0.55
Tobacco (pounds)	1.90	1.84	1.79	1.77	1.74
Cottonseed (tons)	102.30	106.40	118.60	139.80	150.00
Soybeans for beans (bushels)	5.73	6.14	7.05	7.58	8.35
Peanuts, for nuts (pounds)	0.19	0.18	0.19	0.19	0.20
Flaxseed (bushels)	5.99	6.29	7.74	9.10	9.12
Apples, all commercial (pounds)	0.17	0.18	0.20	0.21	0.23
Oranges, all types (boxes)	6.12	6.66	7.90	8.62	9.28
Grapefruit, all types (boxes)	7.09	8.38	9.89	9.34	9.58
Potatoes (cwt)	6.45	6.51	6.68	7.32	7.84
Sweet potatoes (cwt)	17.38	17.96	18.26	18.66	19.52
Steers and Heifers (cwt)	82.78	86.22	91.28	93.34	92.38
Cows for slaughter (cwt)	44.62	45.76	47.88	49.42	48.32
Calves (cwt)	111.68	117.08	121.60	123.20	120.40
Sheep (cwt)	36.26	36.38	37.00	35.46	34.20
Lambs (cwt)	89.22	94.94	99.88	100.92	100.64
Hogs (cwt)	42.90	43.20	45.86	47.82	46.28
Milk (cwt)	14.22	13.80	15.21	16.39	15.75
Broilers, commercial (pounds)	0.39	0.38	0.41	0.43	0.43
Turkeys (pounds)	0.40	0.46	0.48	0.50	0.50
Eggs (dozens)	0.64	0.63	0.69	0.76	0.78
Wool (pounds)	0.62	0.69	0.758	0.81	0.95

1/ Prices for crops and milk are for marketing years; for livestock and wool, calendar years.

Attachment 2
USDA Economic Research Service 2012
State Level Normalized Prices

Table 4—State-level normalized price estimates for commodities, 2012

State	Wheat, all types 1/ (bushel)	Rye 1/ (bushel)	Rice 1/ (cwt.)	Corn for grain 1/ (bushel)	Oats 1/ (bushel)	Barley 1/ (bushel)	Sorghum grain (cwt.)	Hay, all types, baled (ton)	Dry beans (cwt.)	Sugar beets 2/ (ton)	Sugar cane for sugar (cwt.)	Cotton, lint (upland) (pound)	Tobacco 3/ (pound)	Cottonseed (ton)	Soybeans for beans (bushel)	Peanuts, for nuts (pound)
Alabama				4.46	2.33			84.11				0.62		137.44	9.65	0.20
Alaska					2.98	3.99		304.36								
Arizona	6.98			4.93		3.69	8.12	141.71				0.65		211.72		
Arkansas	4.96		12.05	4.00			6.53	79.53				0.58		176.23	9.28	
California	5.55		20.68	4.43	3.41	4.05		137.45	49.34	54.26		0.74		230.97		
Colorado	5.18			4.01	2.91	4.25	6.64	138.11	28.76	52.06						
Connecticut								197.02								
Delaware	4.53			4.57		2.55		159.38							9.58	
Florida	4.59			4.14				136.47			33.66	0.61		141.95	8.91	0.20
Georgia	4.72	6.95		4.56	2.43		7.10	81.49				0.66	1.66	137.44	9.52	0.20
Hawaii											38.38					
Idaho	5.30			4.33	2.37	4.53		141.71	28.95	44.14						
Illinois	4.79			4.01	2.85		7.42	124.69							9.77	
Indiana	4.74			4.12	3.55			125.35							9.68	
Iowa	4.72			4.05	2.45			113.89							9.50	
Kansas	5.23			3.94	2.59	2.64	6.60	104.40	27.03			0.66		131.42	9.30	
Kentucky	4.94			4.15				99.33					1.75		9.62	
Louisiana	4.65		12.24	4.04			6.41	92.95			33.03	0.61		169.92	9.12	
Maine					1.73	2.54		150.87								
Maryland	4.59			4.45		2.60		158.07							9.43	
Massachusetts								193.09								
Michigan	4.83			4.05	2.56	2.54		121.58	31.43	53.83					9.36	
Minnesota	5.54			3.89	2.16	3.97		107.02	31.46	51.14					9.34	
Mississippi	4.51		11.78	3.99			5.84	65.13				0.60		157.89	8.89	0.20
Missouri	4.52		11.45	4.09	2.98		7.38	78.38				0.54		178.94	9.54	
Montana	5.67			4.40	2.62	4.40		95.40	27.62	51.42						
Nebraska	5.17			3.99	2.78		6.63	78.05	28.76	54.41					9.30	
Nevada	5.28							137.13								
New Hampshire								186.22								
New Jersey	4.66			4.37				127.64							9.47	
New Mexico	5.27			4.53			7.23	161.67	39.05			0.66		199.69		0.27
New York	5.37			4.59	2.35	3.56		118.47	37.72						9.46	
North Carolina	4.68			4.39	2.73	2.93		89.51				0.58	1.68	142.85	9.50	0.23
North Dakota	5.81			3.74	2.31	3.82		66.11	25.14	52.82					9.18	
Ohio	4.78			4.14	3.05			121.75					1.59		9.70	
Oklahoma	5.23	6.44		4.02	3.20		6.77	85.25				0.65		142.85	9.19	0.22
Oregon	5.48			4.46	2.42	3.16		162.98	29.23	44.14						
Pennsylvania	4.50			4.43	2.89	3.22		138.76					1.64		9.74	
Rhode Island								193.75								
South Carolina	4.71			4.37	2.43			104.73				0.60	1.70	145.26	9.31	0.23
South Dakota	5.71			3.79	2.35	3.21	6.27	82.47	27.06						9.13	
Tennessee	4.83			4.05				84.27				0.62	2.02	178.04	9.30	
Texas	5.61		12.30	4.23	4.01		6.63	119.78	30.81		25.03	0.57		161.50	8.88	0.23
Utah	6.61			4.60	2.95	3.11		122.73								
Vermont								147.93								
Virginia	4.69			4.30	2.47	2.75		135.16				0.54	1.71	160.89	9.37	0.23
Washington	5.38			4.78	2.47	3.00		164.62	29.32							
West Virginia	4.74			4.28				93.60							9.63	
Wisconsin	4.61			3.99	2.21	2.63		101.45	40.26						9.28	
Wyoming	5.14			4.27	2.82	4.38		99.33	30.03	53.77						

1/ Does not include deficiency payments.

2/ Does not include payments under the sugar act.

3/ Prices based on a 480-pound net-weight bale.

4/ Both fresh and processed sale prices (equivalent packinghouse-door returns for Washington and Oregon, equivalent first delivery point for California, and "as sold" for other States).

5/ Equivalent packinghouse-door returns per box for all uses.

6/ Sold to plants and dealers.

Note: Blank cells indicate no data. Turkeys are no longer reported by NASS for States.

Source: USDA, Economic Research Service, using data from USDA, National Agricultural Statistics Service.

Flaxseed (bushel)	Apples, all commercial /4 (pound)	Oranges, all types (box)	Grapefruit, all types /5 (box)	Potatoes (cwt.)	Sweet potatoes (cwt.)	Steers and Heifers (cwt.)	Cows for Slaughter (cwt.)	Calves (cwt.)	Sheep (cwt.)	Lambs (cwt.)	Hogs (cwt.)	Milk /6 (cwt.)	Broilers, commercial (pound)	Eggs (dozen)	Wool (pound)
					12.38	84.91	46.17	103.89			45.61	19.02	0.45	1.50	
				22.74		120.68	86.35	126.65			87.39	24.27			
	0.22			14.40		92.12	50.96	114.69	36.60	96.54	56.56	15.27			0.26
						95.64	47.21	110.01			43.60	16.87	0.44	1.40	
	0.26	13.52	9.63	12.34	25.77	91.82	46.07	111.87	32.42	91.43	47.88	14.40		0.79	0.98
	0.25			9.51		98.83	51.35	119.97	35.60	102.59	48.71	15.94		0.83	1.05
	0.55					64.70	43.01	103.78			42.21	17.58		0.70	
				10.15		90.18	52.78	106.95			44.98	17.18	0.49		
		11.97	8.49	16.12		88.00	47.96	106.81			44.95	20.15	0.45	0.74	
						88.00	51.25	105.89			48.08	18.05	0.45	1.21	
						59.64	28.77	92.88			96.16	33.81		1.16	
	0.23			6.78		91.32	49.04	112.93	28.54	101.82	47.16	14.66			0.99
	0.56			8.15		91.28	49.59	109.55	35.63	101.98	48.12	16.74		0.73	0.33
	0.38					89.41	48.65	104.28	34.16	105.81	48.97	16.84		0.72	0.24
	0.67					91.85	50.89	116.45	34.51	101.11	47.92	16.14		0.69	0.28
				10.85		92.79	49.69	125.95	27.29	100.06	42.41	16.81			0.45
						91.85	48.61	107.20	42.15	109.65	45.64	17.41	0.45	1.12	0.38
					17.58	89.14	47.08	105.08			39.21	17.71		1.04	
	0.45			9.32		68.72	43.34	103.78			42.21	18.11		0.84	
	0.18			9.10		86.36	51.84	106.95			45.21	17.38	0.49	0.78	
	0.54			10.34		65.03	42.68	103.78			42.21	17.58		0.85	
	0.18			9.84		85.52	49.46	98.96	36.60	104.22	42.71	16.61		0.70	0.41
10.42	0.74			7.23		89.10	52.23	122.43	34.45	106.10	48.68	16.27	0.45	0.75	0.33
					18.75	86.25	47.28	102.02			44.32	17.91	0.45	1.30	
	0.29			8.87		99.60	46.82	116.80	38.39	105.49	41.98	16.24		0.85	0.47
11.52				10.52		101.07	47.57	121.37	31.81	108.05	46.17	16.91		0.75	1.26
				9.04		93.26	52.69	127.00	37.72	104.73	48.77	16.61	0.47	0.70	0.43
						98.22	48.55	122.43	37.88	108.05	45.25	15.13			1.18
	0.48					65.37	43.01	107.30			42.21	17.31			
	0.48			10.68	27.99	67.72	47.90	85.49			39.77	16.10			
						95.71	52.75	118.21	37.53	109.65	40.46	15.20			1.29
	0.19			13.27		86.69	48.91	99.03	46.26	115.40	39.28	16.81		0.72	0.31
10.37	0.18			9.81	17.71	88.40	50.31	101.71	40.13	110.93	47.82	18.75	0.49	1.23	0.52
				8.28		97.45	50.21	115.74	29.18	108.69	46.99	15.87			0.74
	0.40			12.27		87.46	45.23	104.28	35.79	107.64	45.64	17.28	0.45	0.71	0.29
						96.81	51.87	118.21	34.35	100.38	39.84	17.68	0.44	1.13	0.43
	0.23			7.85		90.28	48.91	108.95	39.33	98.72	51.25	16.51		0.82	0.68
	0.17			11.90		86.09	48.94	110.43	49.47	116.36	43.86	17.64	0.47	0.71	0.31
	0.74			11.68		64.03	44.96	103.78			42.21	17.51			
						85.75	48.13	100.72			48.31	19.18	0.47	0.90	
9.73						97.65	51.94	122.78	31.20	113.49	47.16	16.54		0.71	0.87
	0.34					91.45	46.85	105.16	38.20	109.01	45.44	17.48	0.45	1.42	0.45
		9.66	8.48	15.62		93.13	45.94	116.80	37.53	109.07	42.31	16.44	0.45	0.90	1.16
	0.29					92.52	45.29	115.74	33.07	104.82	52.93	15.57		0.76	0.98
	0.32					65.37	44.31	105.54			42.21	17.07		0.83	
	0.16			13.80		90.48	46.11	105.96	39.29	113.49	46.90	18.85	0.45	1.12	0.48
	0.27			6.95		95.81	48.06	105.37	32.52	103.58	45.94	15.40		0.82	1.29
	0.15					83.00	47.31	95.90	35.12	109.65	48.31	16.27	0.47	1.44	0.41
	0.50			9.60		83.77	48.42	146.70	35.41	101.88	44.16	16.10	0.47	0.74	0.38
						102.14	47.21	123.84	34.61	104.22	42.87	15.97		0.71	1.34

Attachment 3
Estimation of Expected Annual Flooding

Based on Table 1.1 DEIS

Year	St. Johns	New Madrid	Total	Cum	discreet	Estimated	Estimated	I
	Acres	Acres	Acres	Prob	Prob	Acres St. Johns	Acres New Madrid	
1	753	404	1157	1.00	0.5000	6328.5	16897.5	3164.3
2	11904	33391	45295	0.50	0.1667	13321.2	37657.5	2220.2
3	14738	41924	56662	0.33	0.0833	16155.5	46190.5	1346.3
4	17573	50457	68030	0.25	0.0500	18989.8	54723.5	949.5
5	20407	58990	79397	0.20	0.0333	21063.5	60165.9	702.1
6	21720	61342	83062	0.17	0.0238	22376.5	62517.7	532.8
7	23033	63694	86727	0.14	0.0179	23689.5	64869.5	423.0
8	24346	66045	90391	0.13	0.0139	25002.5	67221.3	347.3
9	25659	68397	94056	0.11	0.0111	26315.5	69573.1	292.4
10	26972	70749	97721	0.10	0.0091	27545.1	71299.5	250.4
11	28118	71850	99968	0.09	0.0076	28691.2	72400.4	217.4
12	29264	72951	102215	0.08	0.0064	29837.3	73501.3	191.3
13	30410	74052	104462	0.08	0.0055	30983.4	74602.2	170.2
14	31556	75153	106709	0.07	0.0048	32129.5	75703.1	153.0
15	32703	76254	108956	0.07	0.0042	33275.6	76804.0	138.6
16	33849	77354	111203	0.06	0.0037	34421.7	77904.9	126.6
17	34995	78455	113450	0.06	0.0033	35567.8	79005.8	116.2
18	36141	79556	115697	0.06	0.0029	36713.9	80106.7	107.4
19	37287	80657	117944	0.05	0.0026	37860.0	81207.6	99.6
20	38433	81758	120191	0.05	0.0024	38517.2	81952.0	91.7
21	38601	82146	120747	0.05	0.0022	38685.5	82339.9	83.7
22	38770	82534	121304	0.05	0.0020	38853.8	82727.8	76.8
23	38938	82922	121860	0.04	0.0018	39022.2	83115.8	70.7
24	39106	83310	122416	0.04	0.0017	39190.5	83503.7	65.3
25	39275	83698	122972	0.04	0.0015	39358.8	83891.6	60.6
26	39443	84086	123529	0.04	0.0014	39527.2	84279.6	56.3
27	39611	84474	124085	0.04	0.0013	39695.5	84667.5	52.5
28	39780	84861	124641	0.04	0.0012	39863.8	85055.4	49.1
29	39948	85249	125197	0.03	0.0011	40032.2	85443.4	46.0
30	40116	85637	125754	0.03	0.0011	40200.5	85831.3	43.2
31	40285	86025	126310	0.03	0.0010	40368.8	86219.2	40.7
32	40453	86413	126866	0.03	0.0009	40537.2	86607.2	38.4
33	40621	86801	127422	0.03	0.0009	40705.5	86995.1	36.3
34	40790	87189	127979	0.03	0.0008	40873.8	87383.0	34.3
35	40958	87577	128535	0.03	0.0008	41042.2	87771.0	32.6
36	41126	87965	129091	0.03	0.0008	41210.5	88158.9	30.9
37	41295	88353	129648	0.03	0.0007	41378.8	88546.8	29.4
38	41463	88741	130204	0.03	0.0007	41547.2	88934.8	28.0
39	41631	89129	130760	0.03	0.0006	41715.5	89322.7	26.7
40	41800	89517	131316	0.03	0.0006	41883.8	89710.6	25.5
41	41968	89905	131873	0.02	0.0006	42052.2	90098.6	24.4
42	42136	90293	132429	0.02	0.0006	42220.5	90486.5	23.4
43	42305	90680	132985	0.02	0.0005	42388.8	90874.4	22.4

Flood Estimate	Within the 5 - year floodplain				% In 5-year Floodplain
	New Madrid	Total	St. Johns	New Madrid	
	Acres	Acres	Acres	Acres	
8448.8	11613.0	3164.3	8448.8	11613.0	100.00%
6276.3	8496.4	2220.2	6276.3	8496.4	100.00%
3849.2	5195.5	1346.3	3849.2	5195.5	100.00%
2736.2	3685.7	949.5	2736.2	3685.7	100.00%
2005.5	2707.6	680.2	1966.3	2646.6	97.74%
1488.5	2021.3	485.9	1404.5	1890.4	93.52%
1158.4	1581.4	364.4	1053.4	1417.8	89.65%
933.6	1280.9	283.4	819.3	1102.7	86.09%
773.0	1065.4	226.7	655.4	882.2	82.80%
648.2	898.6	185.5	536.3	721.8	80.33%
548.5	765.8	154.6	446.9	601.5	78.54%
471.2	662.4	130.8	378.1	509.0	76.83%
409.9	580.1	112.1	324.1	436.2	75.20%
360.5	513.5	97.2	280.9	378.1	73.63%
320.0	458.7	85.0	245.8	330.8	72.13%
286.4	413.0	75.0	216.9	291.9	70.68%
258.2	374.4	66.7	192.8	259.5	69.30%
234.2	341.6	59.7	172.5	232.2	67.96%
213.7	313.3	53.7	155.2	208.9	66.68%
195.1	286.8	48.6	140.5	189.0	65.91%
178.2	262.0	44.2	127.7	171.9	65.60%
163.5	240.3	40.3	116.6	156.9	65.30%
150.6	221.3	37.0	106.9	143.8	65.01%
139.2	204.5	34.0	98.3	132.3	64.71%
129.1	189.6	31.4	90.8	122.1	64.42%
120.1	176.4	29.1	84.0	113.1	64.13%
112.0	164.5	27.0	78.0	105.0	63.84%
104.7	153.8	25.1	72.6	97.8	63.56%
98.2	144.2	23.5	67.8	91.3	63.28%
92.3	135.5	21.9	63.4	85.4	63.00%
86.9	127.6	20.6	59.5	80.0	62.72%
82.0	120.4	19.3	55.9	75.2	62.45%
77.5	113.8	18.2	52.6	70.8	62.17%
73.4	107.8	17.1	49.6	66.7	61.90%
69.7	102.2	16.2	46.8	63.0	61.64%
66.2	97.1	15.3	44.3	59.6	61.37%
63.0	92.4	14.5	42.0	56.5	61.11%
60.0	88.0	13.8	39.8	53.6	60.85%
57.3	84.0	13.1	37.8	50.9	60.59%
54.7	80.2	12.4	36.0	48.4	60.33%
52.3	76.7	11.9	34.3	46.1	60.08%
50.1	73.5	11.3	32.7	44.0	59.83%
48.0	70.4	10.8	31.2	42.0	59.58%

46.1	67.6	10.3	29.8	40.1	59.33%
44.3	64.9	9.9	28.5	38.4	59.09%
42.6	62.4	9.4	27.3	36.7	58.84%
41.0	60.1	9.0	26.1	35.2	58.60%
39.5	57.8	8.7	25.1	33.8	58.36%
38.0	55.8	8.3	24.1	32.4	58.12%
1867.9	2737.6	408.1	1179.8	1587.9	58.01%
35,863.7	49488.1	11,761.6	33,108.4	44870.0	90.67%

3735.8	5475.2	408.1	1179.8	1587.9	29.00%
37731.6	52225.7	11761.6	33108.4	44870.0	85.92%

Assuming Flood Events above the 50 Year Event Impact 136,879 Acres			
Summary			
Expected Annual Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	11,761.6	33,108.4	44,870.0
above 5 year floodplain	1,862.8	2,755.3	4,618.1
Total	13,624.4	35,863.7	49,488.1
Total Acres (Within the 50 Year Floodplain)			
	SJBB	NM	Total
0-5 year floodplain	20,407	58,990	79,397
above 5 year floodplain	23,076	34,406	57,482
Total	43,483	93,396	136,879

Assuming Flood Events above the 50 Year Event Impact 273,758 Acres			
Summary			
Expected Annual Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	11,761.6	33,108.4	44,870.0
above 5 year floodplain	2,732.4	4,623.2	7,355.6
Total	14,494.1	37,731.6	52,225.7
Difference	869.7	1,867.9	2,737.6

SJBB - Pages 8&9 c	
5-Year Floodplain	70%
50-year Floodplain	78%

NMF - Pages 12&13	
5-Year Floodplain	80%
50-year Floodplain	83%
Above 50-year Floodplain	90%

Assuming Flood Events above the 50 Year Event Impact 136,879 Acres	
Summary	
Estimated Annual Crop Acres	
	SJBB
0-5 year floodplain	8,233.1
above 5 year floodplain	2,393.9
Total	10,627.0
Estimated Crop Acres (Within the 50 Year Floodplain)	
	SJBB
0-5 year floodplain	14,285
above 5 year floodplain	19,632
Total	33,917

Assuming Flood Events above the 50 Year Event Impact 273,758 Acres	
Summary	
Expected Annual Acres Flooded	
	SJBB
0-5 year floodplain	8,233.1
5 to 50 year floodplain	2,393.9
Above 50 year floodplain	782.7
Total	11,409.7

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50 Year Event Impact		
Acres Flooded		
NM	Total	
26,486.7	34,719.8	
3,280.1	5,674.0	
29,766.9	40,393.9	
50 Year Floodplain)		
NM	Total	
47,192	61,477	
30,327	49,959	
77,519	111,435	

50 Year Event Impact		
s Flooded		
NM	Total	
26,486.7	34,720	
3,280.1	5,674	
1,681.1	2,464	
31,448.0	42,857.7	

Summary			
Estimated Annual Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	11,761.6	33,108.4	44,870.0
above 5 to 50 year floodplain	1,862.8	2,755.3	4,618.1
Above 50 year floodplain (est)	869.7	1,867.9	2,737.6
Total	14,494.1	37,731.6	52,225.7

Summary			
Estimated Annual Crop Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	8,233.1	26,486.7	34,719.8
above 5 to 50 year floodplain	2,393.9	3,280.1	5,674.0
Above 50 year floodplain (est)	782.7	1,681.1	2,463.8
Total	11,409.7	31,448.0	42,857.7

Based on Table 3 Appendix D

	Estimated					Estimated		
	St. Johns	New Madrid	Total	Cum	discreet	Acres	Acres	St. Johns
Year	Acres	Acres	Acres	Prob	Prob	St. Johns	New Madrid	Acres
1	0	0	0	1.00	0.5000	5028.0	8658.0	2514.0
2	10056	17316	27372	0.50	0.1667	13385.3	20326.8	2230.9
3	16715	23338	40052	0.33	0.0833	20044.0	26348.5	1670.3
4	23373	29359	52733	0.25	0.0500	26702.7	32370.2	1335.1
5	30032	35381	65413	0.20	0.0333	30444.3	37194.8	1014.8
6	30857	39009	69865	0.17	0.0238	31268.9	40822.4	744.5
7	31681	42636	74317	0.14	0.0179	32093.5	44450.0	573.1
8	32506	46264	78770	0.13	0.0139	32918.1	48077.6	457.2
9	33330	49891	83222	0.11	0.0111	33742.7	51705.2	374.9
10	34155	53519	87674	0.10	0.0091	34352.3	54072.0	312.3
11	34550	54625	89174	0.09	0.0076	34746.8	55177.9	263.2
12	34944	55731	90675	0.08	0.0064	35141.3	56283.8	225.3
13	35339	56837	92175	0.08	0.0055	35535.9	57389.8	195.3
14	35733	57943	93676	0.07	0.0048	35930.4	58495.7	171.1
15	36128	59049	95176	0.07	0.0042	36324.9	59601.6	151.4
16	36522	60155	96677	0.06	0.0037	36719.5	60707.6	135.0
17	36917	61261	98177	0.06	0.0033	37114.0	61813.5	121.3
18	37311	62366	99678	0.06	0.0029	37508.5	62919.4	109.7
19	37706	63472	101178	0.05	0.0026	37903.1	64025.4	99.7
20	38100	64578	102679	0.05	0.0024	38297.6	65131.3	91.2
21	38495	65684	104179	0.05	0.0022	38692.1	66237.2	83.7
22	38889	66790	105680	0.05	0.0020	39086.7	67343.2	77.2
23	39284	67896	107180	0.04	0.0018	39481.2	68449.1	71.5
24	39678	69002	108681	0.04	0.0017	39875.7	69555.0	66.5
25	40073	70108	110181	0.04	0.0015	41565.7	70605.0	63.9
26	43058	71102	114160	0.04	0.0014	44551.1	71599.0	63.5
27	46044	72096	118140	0.04	0.0013	47536.5	72593.0	62.9
28	49029	73090	122119	0.04	0.0012	50521.9	73587.0	62.2
29	52015	74084	126099	0.03	0.0011	53507.3	74581.0	61.5
30	55000	75078	130078	0.03	0.0333	55000.0	75078.0	1833.3
TOTAL								15,236.6
Adjustments for lack of data above 30 year event								
30	55000	75078	130078	0.03	0.0333	110000.0	150156.0	3666.7
								17069.9

Flood Estimate New Madrid	Within the 5 - year floodplain				% In 5-year Floodplain
	Total Acres	St. Johns Acres	New Madrid Acres	Total Acres	
4329.0	6843.0	2514.0	4329.0	6843.0	100.00%
3387.8	5618.7	2230.9	3387.8	5618.7	100.00%
2195.7	3866.0	1670.3	2195.7	3866.0	100.00%
1618.5	2953.6	1335.1	1618.5	2953.6	100.00%
1239.8	2254.6	1001.1	1179.4	2180.4	96.71%
972.0	1716.5	715.0	842.4	1557.5	90.74%
793.8	1366.8	536.3	631.8	1168.1	85.46%
667.7	1124.9	417.1	491.4	908.5	80.76%
574.5	949.4	333.7	393.1	726.8	76.55%
491.6	803.9	273.0	321.6	594.7	73.98%
418.0	681.2	227.5	268.0	495.6	72.74%
360.8	586.1	192.5	226.8	419.3	71.55%
315.3	510.6	165.0	194.4	359.4	70.39%
278.6	449.6	143.0	168.5	311.5	69.27%
248.3	399.7	125.1	147.4	272.6	68.19%
223.2	358.2	110.4	130.1	240.5	67.14%
202.0	323.3	98.1	115.6	213.8	66.12%
184.0	293.6	87.8	103.5	191.3	65.13%
168.5	268.2	79.0	93.1	172.1	64.18%
155.1	246.3	71.5	84.2	155.7	63.24%
143.4	227.1	65.0	76.6	141.6	62.34%
133.1	210.3	59.4	69.9	129.3	61.46%
124.0	195.5	54.4	64.1	118.5	60.61%
115.9	182.4	50.1	59.0	109.0	59.78%
108.6	172.6	46.2	54.4	100.6	58.32%
102.0	165.5	42.8	50.4	93.2	56.32%
96.0	158.9	39.7	46.8	86.5	54.45%
90.6	152.8	37.0	43.6	80.6	52.71%
85.7	147.2	34.5	40.7	75.2	51.07%
2502.6	4335.9	1001.1	1179.4	2180.4	50.29%
22,326.1	37562.7	13,756.8	18,607.2	32364.0	86.16%
5005.2	8671.9	1001.1	1179.4	2180.4	25.14%
24828.7	41898.6	13756.8	18607.2	32364.0	77.24%

Assuming Flood Events above the 30 Year Event Impact 130,078 Acres			
Summary			
Expected Annual Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	13,756.8	18,607.2	32,364.0
above 5 year floodplain	1,479.8	3,718.9	5,198.7
Total	15,236.6	22,326.1	37,562.7
Total Acres (Within the 30 Year Floodplain)			
	SJBB	NM	Total
0-5 year floodplain	30,032	35,381	65,413
above 5 year floodplain	24,968	39,697	64,665
Total	55,000	75,078	130,078

Assuming Flood Events above the 30 Year Event Impact 260,156 Acres			
Summary			
Expected Annual Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	13,756.8	18,607.2	32,364.0
above 5 year floodplain	3,313.2	6,221.5	9,534.6
Total	17,069.9	24,828.7	41,898.6
Difference	1,833.3	2,502.6	4,335.9

SJBB - Pages 8&9 c	
5-Year Floodplain	70%
50-year Floodplain	78%

NMF - Pages 12&13	
5-Year Floodplain	80%
50-year Floodplain	83%

Assuming Flood Events above the 30 Year Event Impact 130,078 Acres	
Summary	
Estimated Annual Crop Acres	
	SJBB
0-5 year floodplain	9,629.7
above 5 year floodplain	2,254.8
Total	11,884.5
Estimated Crop Acres (Within the 30 Year Floodplain)	
	SJBB
0-5 year floodplain	21,022
above 5 year floodplain	21,878
Total	42,900

Assuming Flood Events above the 30 Year Event Impact 260,156 Acres	
Summary	
Expected Annual Crop Acres	
	SJBB
0-5 year floodplain	9629.7
5 - 30 year flood plain	2254.8
above 30 year flood plain	1430.0
Total	13314.5

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Summary			
Estimated Annual Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	13,756.8	18,607.2	32,364.0
above 5 to 30 year floodplain	1,479.8	3,718.9	5,198.7
Above 30 year floodplain (est)	1,833.3	2,502.6	4,335.9
Total	17,069.9	24,828.7	41,898.6

30 Year Event Impact		
Acres Flooded		
NM	Total	
14,885.8	24,515.5	
3,644.9	5,899.7	
18,530.7	30,415.2	
30 Year Floodplain)		
NM	Total	
28,305	49,327	
34,010	55,888	
62,315	105,215	

Summary			
Estimated Annual Crop Acres Flooded			
	SJBB	NM	Total
0-5 year floodplain	9,629.7	14,885.8	24,515.5
above 5 to 30 year floodplain	2,254.8	3,644.9	5,899.7
Above 30 year floodplain (est)	1,430.0	2,077.2	3,902.3
Total	13,534.5	20,783.0	34,317.5

30 Year Event Impact		
Acres Flooded		
NM	Total	
14885.8	24515.5	
3644.9	5899.7	
2077.2	3507.2	
20607.8	33922.4	

Attachment 4
2002 Revised Supplemental Environmental Impact Statement –
Appendix B

Appendix B

ECONOMICS AND SOCIAL ANALYSIS

Part 1

2002 RSEIS

Appendix B

ECONOMICS OF ALTERNATIVES

INTRODUCTION

The purpose of this section is to present information pertaining to the annual benefits, costs, and economic justification of the alternatives that have been developed to address the flooding problems faced by the East Prairie, Missouri area. Alternatives presented in this section include a no action alternative, the alternative recommended in the March 1997 St. Johns Bayou and New Madrid Floodway Missouri First Phase Limited Reevaluation Report (LRR), more environmentally sensitive versions of this plan, new levee closure alignments, a ring levee around East Prairie, and various non-structural alternatives. Each of these alternatives is described in later paragraphs.

GENERAL

For the purpose of this section, construction is assumed to begin in fiscal year 1997 and to be completed in fiscal year 2002. This assumption was made for comparability purposes with the LRR and because a small portion of this project has already been constructed on the upper reach of Birds Point Levee Ditch. This construction schedule is not comparable with other parts of this report. A further assumption was made to not consider the completed work as sunk, but to consider all expenditures as remaining. The period of analysis is from the end of 2002 (beginning of 2003) through the end of 2052. For discounting purposes, costs are assumed to take place at the end of the year during which they are expended and benefits related to the physical construction from such costs are assumed to accrue one year after construction is completed. All benefits and costs accruing prior to the end of 2002 were compounded forward, and those occurring after the end of 2002 were discounted backward to determine the present value of project benefits and costs as of the end of 2002. The sum of the present values for each category was amortized over the period of analysis (50 years) to obtain average annual uniform equivalent values. The First Phase feature of Alternative 2 and Alternative 4 (described in later sections) were chosen to illustrate the methodology used to calculate annual economic benefits and costs in this appendix. These features are chosen for illustration purposes only and may or may not be recommended for construction.

The price levels and much of the land use used in this section are the same as used in the LRR (1996). The only deviation from the information used in the LRR was for the New Madrid Floodway Closure. The analysis in the LRR assumed that the closure was in place. This necessitated the development of land use and crop budgets absent the closure. Estimates of land use are based on the LRR and information obtained from area farmers, the University of Missouri Office of Social and Economic Data Analysis, and the USDA Census of Agriculture. The area is predominately rural and dependent on agriculture for its livelihood. Little urban development occurs in the area.

Two interest rates are used in this section. The Mississippi River Levees feature consisting of a 1,500-foot levee closure and gravity structure at the south end of the New Madrid Floodway was

analyzed using a previously authorized interest rate of 2.5%. The remaining features were analyzed using the interest rate presented in the LRR (7 3/8%).

ALTERNATIVES

A total of nine alternatives are presented in this section. Alternatives 1 through 5, 7 and 9 were carried into a more detailed economic analysis. Alternatives 6 and 8 were initially screened from further analysis. Further, Alternative 1 is the "No Action" alternative or existing conditions, which is the base from which all other alternatives are measured. A brief description of each alternative is presented in the following paragraphs.

Alternative 1. Alternative 1 is the "No Action" alternative. This is the same as existing conditions and forms the basis by which the other alternatives are measured.

Alternative 2. Alternative 2, referred to in this section as the "Authorized" alternative, is part of the total project authorized by the Water Resources Development Act of 1986. It is also the alternative presented in the LRR with the addition of the Mississippi River Levee (MRL) feature. The MRL feature consists of a 1,500-foot levee closure and gravity structure at the south end of the New Madrid Floodway, which will prevent backwater flooding from the Mississippi River. The remainder of Alternative 2 is referred to as the First Phase feature in this section. The First Phase feature consists of two pumping stations, a 1,500 cfs station in the New Madrid Floodway basin and a 1,000 cfs station in the St Johns Bayou basin. Also included is 4.5 miles of channel enlargement on St Johns Bayou, 8.1 miles on Birds Point Levee Ditch, and 10.8 miles on St James Ditch. The channel work is designed to drain the area in the vicinity of East Prairie, Missouri. All of the channel work occurs within the St Johns Bayou basin. No channel improvement occurs within the New Madrid Floodway basin.

Alternative 3. Alternative 3 is a series of refinements of Alternative 2, which incorporates many features to lessen potential environmental effects. It eliminated a reach of St James Ditch to avoid an area which contains a State of Missouri listed endangered species. It also included single-sided channel work, a 67% reduction in channel design width for St Johns Bayou, and rock structures in channels. Four additional New Madrid Floodway levee closure locations were analyzed along with two additional start-stop pump/gate closure elevations. Other environmental features include establishing a riparian corridor along the improved channels and seasonal flooding of up to 6,400 acres during the winter for migratory waterfowl.

Alternative 4. Alternative 4 is a ring levee around the town of East Prairie, Missouri to protect it from headwater flooding associated with St James Ditch. St James Ditch is the drainage outlet for East Prairie and the primary source of flooding in the community's industrial park. Two designs providing 25 and 100-year levels of protection were considered as part of this alternative. The interior drainage improvements developed as part of this alternative were analyzed not only with this alternative, but also with the St James Ditch improvements of Alternative 3.

Alternative 5. Alternative 5 consists of the St Johns Bayou Basin portion of Alternative 3. It includes the St Johns Bayou pumping station and channel work on St Johns Bayou, Birds Point Levee Ditch, and St James Ditch but excludes the New Madrid Floodway's closure and pumping station.

Alternative 6. Alternative 6 consists of a wildlife refuge located in the lower reaches of the St Johns Bayou Basin and the New Madrid Floodway. The U.S. Fish and Wildlife Service previously studied this alternative in great detail. It proposed purchasing the lower portions of both basins and converting them to high quality wildlife and fishery habitat. The Service tabled this proposal around 1993. While it found the proposal to be technically feasible, it was considered unimplementable. The local community would not support the proposal and provide the necessary lands even at a fair market value. Because of the above and since it does not reasonably address all of the area's flood problems, this alternative was not carried into a detailed economic analysis.

Alternative 7. Alternative 7 is comprised of three additional New Madrid Floodway levee and pump station alignments not included in Alternatives 2 and 3. They are located further inside the New Madrid Floodway. Alternative 7-1, starting from Tenmile Pond and extending along St James Bayou to tie into the Frontline Levee southeast of Big Oak Tree State Park, was studied in detail during the Phase I GDM, which was a prior feasibility study conducted during the 1980's. At that time it was found not to be economically feasible. However, it was investigated again to see if conditions have changed since the Phase I GDM. Alternatives 7-2 and 7-3 are new alternatives.

Alternative 8. Alternative 8 would convert frequently flooded cropland in both basins to woodland through a proposal similar to the Wetland Reserve Program (WRP). It would reduce flood damages by changing the existing land use but would not provide any flood protection. The WRP has been available to the local community for many years. With a very few exceptions, no one has chosen to participate. One of the main reasons that the area's landowners chose not to participate in WRP is that the area's farmland is not marginal. It is prime farmland. The majority of lands that have been enrolled in WRP or the Conservation Reserve Program probably should never have been cleared and put into row-crop production in the first place. High soybean prices in the 1970's induced these marginal lands to be cleared. Most of the St Johns Bayou basin and the New Madrid Floodway basin was cleared and in production prior to this time. Also, there is another economic disincentive for the landowners to participate in the WRP. Cleared land in the project area sells for approximately \$1,600 per acre while woodland sells for around \$700 per acre. A landowner would face a \$900 per acre reduction in land value that would take many years of substantial WRP payments to recoup. For these reasons, it is reasonable to conclude that landowners will continue this trend or choice absent additional incentives, making this alternative not implementable. Because of this Alternative 8, or reforestation with WRP as the primary incentive, was not carried into a detailed economic analysis. However, the basic concept of reforestation was carried over into one of the components of Alternative 9 that uses other incentives to promote reforestation.

Alternative 9. Alternative 9 is a combination of non-structural measures developed for both the urban and rural areas. Included in the urban measures are floodplain evacuation, flood proofing of residences and businesses, and restrictions on future development. Measures developed for the rural area include flood easements, restrictive easements, and changes in land use similar to

Alternative 8 above. The primary difference between the change in land use measure of this alternative and Alternative 8 is that it uses additional incentives to induce the area's landowners to participate.

METHODOLOGY USED TO ESTIMATE ANNUAL DAMAGES AND BENEFITS

The benefits consist of agricultural benefits, urban benefits, streets and roads, advanced replacements and betterments, etc. The agricultural benefits are composed of inundation reduction (flood damage reduction) and intensification. Urban benefits and streets and roads benefits are both inundation reduction benefits. The advanced replacement and betterment benefits offset the added costs of extending the functional life or improving the safety of bridges replaced by the project. The First Phase feature of Alternative 2 is used as an example to present the procedures and methodology used in the agricultural benefit and the cost computations. Alternative 4, which is comprised of the improvements to the East Prairie, Missouri urban area is used to show the procedures and methodology used for the urban and street and road benefits.

AGRICULTURAL BENEFITS.

The agricultural benefits are classified into two categories: inundation reduction (flood damage reduction) and intensification. Inundation reduction benefits consist of damage reduction to development under present and projected future changes under without project conditions. Intensification benefits result from additional income that would be obtained as a result of changes in development caused by the project.

a. Land Use. The area is characterized primarily by agricultural operations. Woodlands are virtually nonexistent. The only areas of woods are scattered and very small. The remaining trees are on spoil banks or channel side slopes of drainage channels or in other low-lying areas. The soils are generally poorly drained and fertile. Because of their favorable properties for agricultural use, these soils have significantly influenced development in the area. There is little urban development occurring in the first phase's project area. The town of East Prairie, Missouri is located in the benefited area. There is also scattered rural development in the form of farm residences and associated buildings, etc. throughout the area. The closest large population center is Sikeston, Missouri, which lies immediately north of the project area.

Future without- and with-project land use is expected to remain essentially the same as current conditions. There are no large tracts of woodlands remaining in the area that can be cleared. The small isolated plots that are left are probably subject to the "Swampbuster" provision of the Food Security Act of 1985 that has effectively halted the clearing of woodlands in most wetland areas. No reversion of cleared lands to woodlands is expected since the cropland is very productive and should be profitable to farm under future without-project conditions. Conversion of croplands to urban use is not expected since there are no urban areas located near the project area with a shortage of non-flood prone lands. The only expected change under future with-project conditions is a change in cropping patterns with a shift from less to more profitable crops due to the decreased

risk of flooding. This impact is not viewed as a change in land use, instead it is viewed as a change in cropping practices.

b. Crop Data. The crop prices used in this section are Normalized Prices developed by the Economic Research Service (ERS). The ERS is one of four agencies in the Research, Education, and Economics Mission Area of the U.S. Department of Agriculture (USDA). The ERS provides economic analysis on efficiency, efficacy, and equity issues related to agriculture, food, the environment, and rural development to improve public and private decision making. Normalized Prices have been used by Federal agencies in water and related land resources planning, since implementation of the Water Resources Planning Act of 1965 which required their use. The ERS annually calculates Normalized Prices for evaluating alternative development and management plans for water and related land resources. Normalized Prices smooth out the effects of short-term price fluctuations so that plans can be evaluated on a more realistic basis rather than using current prices, which may be lower or higher than normal because of short-lived phenomena. The ERS estimates these prices based on 5-year moving averages of actual market prices.

The 1996 price levels used in this section were chosen to make this analysis more comparable to the 1997 Limited Reevaluation Report (LRR) which is the basis or decision document for economic justification. The 1996 prices for the major field crops were some of the lowest of the last 7 years for which Normalized Prices are available. The prices for soybeans were \$6.03, \$5.94, \$5.77, \$5.68, \$5.95, \$6.17, and \$6.46 per bushel for the years 1993 through 1999. Quite obviously, the 1996 price of \$5.68 per bushel is the lowest. The same can be said for corn with prices of \$2.36, \$2.40, \$2.39, \$2.33, \$2.54, \$2.64, and \$2.73 for the same time period. Again, the 1996 price of \$2.33 is the lowest in the 7-year timeframe. Using the lower 1996 prices was not considered to be a problem since higher prices would only increase the project's benefits which would yield higher benefit to cost ratios.

Flooding plays an important role in a farmer's decision-making process. As the risk of flooding increases, a farmer is less likely to plant higher value crops and use high management production techniques. The project area can be divided into flood zones where these significant changes in cropping practices occur. Dividing the agricultural sector into flood zones helps to better evaluate impacts on the agricultural sector. The crop yields used in this analysis are also affected by flood risk and reflected by the differences between the flood zones. The yields in the lower zone are considered flood risk constrained while those in the upper zone are considered non-flood risk constrained crop management practices. Flood risk constrained management is a condition where flood risk/uncertainty causes inefficient crop management practices. However, with non-flood risk constrained management, there are no inefficiencies. This section used the 3-year flood zone as the point where significant changes in farming practices occur in both the St Johns Bayou and the New Madrid Floodway Basins. The area above the 3-year frequency is where more intensive and profitable crops are grown while slightly lower value crops are grown below the 3-year flood zone.

(1). MRL Feature Data. The primary crops grown in the New Madrid Floodway, absent the MRL Feature, are soybeans, corn, grain sorghum, and wheat. Soybeans are the primary cash crop in the lower portion that is subject to frequent backwater flooding. Table 1 presents 1996 land use and crop data used to assess the effects of the MRL feature of Alternatives 2 and 3. Land

use for future (2050) conditions was also estimated. The calculation of future crop budgets was accomplished by projecting both crop yields per acre and levels of crop production inputs per acre. The price levels for both crops and production costs were held constant at 1996 price levels. The methodology used to project crop yields and levels of production inputs is consistent with that used for other Memphis District flood control studies. A first-degree polynomial function was fit to crop budget input and output indices published by the Economic Research Service of the U.S. Department of Agriculture. The resulting regression equations were $y=0.0167348X-32.4349327$ for crop yields and $y=0.0051037X-9.1882495$ for production inputs. The correlation coefficients were 0.94873 and 0.37086 respectively. The output equation tested statistically significant at the 1 percent level of significance, while the input equation tested significant at the 2 percent level. Projected crop data is presented in Table 2.

(2). First Phase Feature Data. Current (1996) crop data for the First Phase features of Alternatives 2 and 3 is presented in Table 3. This data reflects current cropping practices within the St Johns Bayou basin, which is already protected from backwater flooding from the Mississippi River. However, it reflects a significant shift in cropping patterns for the New Madrid Floodway basin. The shift is primarily away from soybeans to more profitable and higher value crops such as corn and double cropping soybeans and wheat. It also reflects a shift to increased use of irrigation in the New Madrid Floodway as farmers increased investments are protected from the frequent backwater flooding. Projected (2050) land use is presented in Table 4. The procedure to project this data is the same as for the MRL feature in the previous paragraph.

c. Agricultural Flood Damage Prevented. Flood damage reduction benefits to crops are based on the difference between average annual equivalent flood damages for without- and with-project conditions. Flood damages are calculated by applying crop damage rates per flooded acre to expected annual acre estimates. This procedure for the First Phase feature of Alternative 2 is described in the following paragraphs.

Table 1
New Madrid Floodway Agricultural Land Use
Existing Conditions
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels

	Corn				Dryland Cotton			Irrigated Cotton		Soybeans			Double Crop Soybeans		Grain Sorghum		
Item	Dryland	Irrigated	Rice	Lint	Seed	Total	Lint	Seed	Total	Dryland	Irrigated	Wheat	Dryland	Irrigated	Dryland	Irrigated	Total
	(bu)	(bu)	(cwt)	(lb)	(ton)		(lb)	(ton)		(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)	
0-3 Year Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26		5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	95.0	0.0	0.00	0	0.000		0	0.000		27.9	33.5	38.0	20.9	25.1	37.80	0.00	
Gross Value	221.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	158.47	190.28	106.78	118.71	142.57	139.10	0.00	
Production Cost	229.41	258.77	425.45			464.96			520.54	109.42	147.62	124.38	109.14	133.50	181.39	232.52	
Net Return	-8.06	0.00	0.00			0.00			0.00	49.05	42.66	-17.60	9.57	9.07	-42.29	0.00	
Distribution	0.060	0.000	0.000			0.000			0.000	0.625	0.145	0.110	0.055	0.055	0.030	0.000	1.080
Wt Net Return	-0.48	0.00	0.00			0.00			0.00	30.66	6.19	-1.94	0.53	0.50	-1.27	0.00	34.19
3 Year-SPF Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26	0.651	5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	124.9	143.0	56.25	677	0.596		794	0.699		33.3	40.5	50.0	26.6	32.3	41.33	58.52	
Gross Value	291.02	333.19	392.63	387.24	53.20	440.44	454.17	62.39	516.56	189.14	230.04	140.50	151.09	183.46	152.09	215.35	
Production Cost	229.41	258.77	425.45			464.96			520.54	109.42	147.62	124.38	109.14	133.50	181.39	232.52	
Net Return	61.61	74.42	-32.82			-24.52			-3.98	79.72	82.42	16.12	41.95	49.96	-29.30	-17.17	
Distribution	0.132	0.091	0.021			0.066			0.046	0.179	0.123	0.124	0.073	0.051	0.106	0.072	1.084
Wt Net Return	8.13	6.77	-0.69			-1.62			-0.18	14.27	10.14	2.00	3.06	2.55	-3.11	-1.24	40.08

Table 2
New Madrid Floodway Basin Agricultural Land Use Projected to 2050
Existing Conditions
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels

	Corn				Dryland Cotton			Irrigated Cotton		Soybeans			Double Crop Soybeans		Grain Sorghum		
Item	Dryland	Irrigated	Rice	Seed	Lint	Total	Seed	Lint	Total	Dryland	Irrigated	Wheat	Dryland	Irrigated	Dryland	Irrigated	Total
	(bu)	(bu)	(cwt)	(lb)	(ton)		(lb)	(ton)		(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)	
0-3 Year Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26		5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	152.0	0.0	0.00	0	0.000		0	0.000		44.6	53.6	60.8	33.4	40.2	60.48	0.00	
Gross Value	354.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	253.56	304.45	170.85	189.94	228.11	222.57	0.00	
Production Cost	282.17	318.29	523.30			571.90			640.26	134.59	181.57	152.99	134.24	164.21	223.11	286.00	
Net Return	71.99	0.00	0.00			0.00			0.00	118.97	122.88	17.86	55.70	63.91	-0.54	0.00	
Wt Production Cost	16.93	0.00	0.00			0.00			0.00	84.12	26.33	16.83	7.38	9.03	6.69	0.00	167.31
Wt Net Return	4.32	0.00	0.00			0.00			0.00	74.36	17.82	1.96	3.06	3.51	-0.02	0.00	105.01
3 Year-SPF Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26		5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	199.8	228.8	90.00	1083	0.954		1270	1.118		53.3	64.8	80.0	42.6	51.7	66.12	93.63	
Gross Value	465.63	533.10	628.20	619.59	85.12	704.71	726.67	99.83	826.50	302.63	368.06	224.80	241.74	293.54	243.34	344.57	
Production Cost	282.17	318.29	523.30			571.90			640.26	134.59	181.57	152.99	134.24	164.21	223.11	286.00	
Net Return	183.46	214.81	104.90			132.81			186.24	168.04	186.49	71.81	107.50	129.34	20.23	58.57	
Distribution	0.132	0.091	0.021			0.066			0.046	0.179	0.123	0.124	0.073	0.051	0.106	0.072	1.084
Wt Net Return	24.22	19.55	2.20			8.77			8.57	30.08	22.94	8.90	7.85	6.60	2.14	4.22	146.04

Table 3
St Johns Bayou and New Madrid Floodway Basins Agricultural Land Use
With the MRL Features
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels

	Corn				Dryland Cotton			Irrigated Cotton		Soybeans			Double Crop Soybeans		Grain Sorghum		
Item	Dryland	Irrigated	Rice	Lint	Seed	Total	Lint	Seed	Total	Dryland	Irrigated	Wheat	Dryland	Irrigated	Dryland	Irrigated	Total
	(bu)	(bu)	(cwt)	(lb)	(ton)		(lb)	(ton)		(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)	
0-3 Year Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26		5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	124.9	143.0	56.25	677	0.596		794	0.699		33.3	40.5	50.0	26.6	32.3	41.33	58.52	
Gross Value	291.02	333.19	392.63	387.24	53.20	440.44	454.17	62.39	516.56	189.14	230.04	140.50	151.09	183.46	152.09	215.35	
Production Cost	229.41	258.77	425.45			464.96			520.54	109.42	147.62	124.38	109.14	133.50	181.39	232.52	
Net Return	61.61	74.42	-32.82			-24.52			-3.98	79.72	82.42	16.12	41.95	49.96	-29.30	-17.17	
Percent Distribution	0.132	0.091	0.021			0.066			0.046	0.179	0.123	0.124	0.073	0.051	0.106	0.072	
Weighted Net Return	8.13	6.77	-0.69			-1.62			-0.18	14.27	10.14	2.00	3.06	2.55	-3.11	-1.24	40.08
3 Year-SPF Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26	0.651	5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	138.8	180.0	56.25	752	0.662		836	0.736		37.0	45.0	50.0	29.6	36.0	45.92	61.60	
Gross Value	323.40	419.40	392.63	430.14	59.09	489.23	478.19	65.70	543.89	210.16	255.60	140.50	168.13	204.48	168.99	226.69	
Production Cost	238.60	279.53	425.45			480.27			529.12	112.99	151.16	124.38	112.44	136.83	186.58	236.01	
Net Return	84.80	139.87	-32.82			8.96			14.77	97.17	104.44	16.12	55.69	67.65	-17.59	-9.32	
Percent Distribution	0.171	0.114	0.021			0.066			0.046	0.182	0.118	0.124	0.073	0.051	0.084	0.054	
Weighted Net Return	14.50	15.95	-0.69			0.59			0.68	17.68	12.32	2.00	4.07	3.45	-1.48	-0.50	68.57

Table 4
St Johns Bayou and New Madrid Floodway Basins Agricultural Land Use Projected to 2050
With the MRL Features
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels

	Corn				Dryland Cotton			Irrigated Cotton		Soybeans			Double Crop Soybeans		Grain Sorghum		
Item	Dryland	Irrigated	Rice	Lint	Seed	Total	Seed	Lint	Total	Dryland	Irrigated	Wheat	Dryland	Irrigated	Dryland	Irrigated	Total
	(bu)	(bu)	(cwt)	(lb)	(ton)		(lb)	(ton)		(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)	
0-3 Year Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26		5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	199.8	228.8	90.00	1083	0.954		1270	1.118		53.3	64.8	80.0	42.6	51.7	66.12	93.63	
Gross Value	465.63	533.10	628.20	619.59	85.12	704.71	726.67	99.83	826.50	302.63	368.06	224.80	241.74	293.54	243.34	344.57	
Production Cost	278.94	306.91	498.00			547.90			617.82	128.71	166.74	148.55	126.69	150.95	209.44	272.24	
Net Return	122.53	155.60	15.66			30.79			66.58	144.32	162.97	42.08	85.91	107.87	-14.27	9.71	
Percent Distribution	0.132	0.091	0.021			0.066			0.046	0.179	0.123	0.124	0.073	0.051	0.106	0.072	
Weighted Net Return	16.17	14.16	0.33			2.03			3.06	25.83	20.05	5.22	6.27	5.50	-1.51	0.70	97.81
3 Year-SPF Floodplain																	
Price	2.33	2.33	6.98	0.572	89.26		0.572	89.26		5.68	5.68	2.81	5.68	5.68	3.68	3.68	
Yield	222.1	288.0	90.00	1203	1.059		1338	1.178		59.2	72.0	80.0	47.4	57.6	73.47	98.56	
Gross Value	517.45	671.04	628.20	688.23	94.54	782.77	765.11	105.11	870.22	336.26	408.96	224.80	269.00	327.17	270.38	362.70	
Production Cost	293.64	340.12	498.00			572.41			631.54	134.42	172.40	148.55	131.96	156.28	217.75	277.81	
Net Return	156.27	252.69	15.66			78.71			93.43	170.92	196.91	42.08	106.69	134.95	2.55	20.99	
Percent Distribution	0.171	0.114	0.021			0.066			0.046	0.182	0.118	0.124	0.073	0.051	0.084	0.054	
Weighted Net Return	26.72	28.81	0.33			5.19			4.30	31.11	23.24	5.22	7.79	6.88	0.21	1.13	140.93

(1) Expected Annual Acres. The number of expected annual cleared acres flooded was calculated by the use of partial duration frequency curves and stage-area information. Results indicate that there are approximately 21,631 expected annual cleared acres flooded by headwater in the project area under existing conditions. The project lowers this figure to 1,271 acres for a reduction of 20,360 or a 94% reduction (Table 5). Backwater floods inundate approximately 35,739 cleared acres under existing conditions. With-project this figure is reduced 58% to 15,115 acres.

Headwater and backwater flooding can and do occur concurrently. To avoid duplication of benefits, the overlapping effect had to be eliminated. From historical hydrologic data, it was determined that when headwater and backwater floods occurred concurrently, the backwater influence was dominant. Therefore, only adjustment of headwater damages was necessary to avoid duplication in the estimation of total damage. Also, from this historical hydrologic data, an estimate was made of the proportion of time that headwater and backwater flooding occurred concurrently. Using this data, factors were developed to reduce the headwater benefits. These factors are presented in Table 6.

(2) Crop Damage Rates. Agricultural crop damage rates were calculated using a computer program entitled Computerized Agricultural Crop Flood Damage Assessment System (CACFDAS), developed by Mississippi State University for the Lower Mississippi Valley Division, Corps of Engineers. This program calculates crop flood damages by analysis of daily flood events. The program also has the capability to calculate damage from multiple flooding events in the same area during the same year. In addition, the program allows for specific crop replanting and/or crop substitution. The program is structured to compute flood damages based on the time of the flood event in relation to the sequence of agricultural operations that have occurred in the production process. Duration factors, expressed as the number of days required to cause damage, are developed for four stages of plant development. Normal, late planting, and last day of planting dates are also developed by crop. These dates are extremely important as they, in conjunction with the duration factors, are the base dates from which flood damages, crop replanting, crop substitution, and crop yield reductions are developed. Three cost vectors were developed for the crop budgets used in the program to assess flood damages. These include: (a) production costs and fixed harvesting equipment costs; (b) expected net returns to lands, management, and general farm overhead; and (c) operation revenues consisting of realized gross value of the harvested crop. Major data requirements include crop distribution, net and gross returns by crop, crop substitution data, daily flood duration data, and cleared acres flooded on a daily basis.

A thorough review of the hydrologic inputs into the CACFDAS program concluded that there were no significant changes in duration, flood elevations, or elevation-area flooded relationships. The only changes to inputs into the CACFDAS program were crop mixes, production costs, crop yields, and crop prices. Current crop mixes, production costs, crop yields, and crop prices were incorporated into the CACFDAS runs to yield the current crop damage rates per acre presented in Tables 5, 6, and 7.

Table 5
Expected Annual Acres Flooded
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS

Item	Without-Project		Recommended Plan		Reduction	
	0-3 Year	3 Yr-SPF	0-3 Year	3 Yr-SPF	0-3 Year	3 Yr-SPF
Headwater						
St Johns Bayou	5,379	90	818	0	4,561	90
St James Ditch	7,365	342	246	0	7,119	342
Birds Point Levee Ditch	8,338	117	207	0	8,131	117
Backwater						
St Johns Pump Station	14,963	3,062	10,952	1,031	4,011	2,031
New Madrid Pump Station						
Lower New Madrid	10,811	1,235	2,684	0	8,127	1,235
St James Bayou	3,488	2,180	448	0	3,041	2,180

Table 6
Backwater-Headwater Overlap Factors
Alternative 2
St Johns Bayou and New Madrid Floodway, EIS

Item	Backwater-Headwater Overlap Factors
St Johns Bayou, Reach 1	0.663
St James Ditch	0.973
BPLD Reach 1	0.854

Table 7
Crop Damage Rates
Alternative 2, First Phase Features
St. Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels

Item	Without-Project		Alternative 2	
	0-3 Year	3 Yr-SPF	0-3 Year	3 Yr-SPF
Headwater				
St. Johns Bayou	50.42	93.58	0.00	0.00
St. James Ditch	32.40	63.73	33.18	0.00
Birds Point Levee Ditch	56.85	65.53	14.42	0.00
Backwater				
St. Johns Pump Station	56.71	109.01	44.48	63.77
New Madrid Pump Station				
Lower New Madrid	74.95	64.65	59.40	0.00
St. James Bayou	39.96	117.85	35.59	23.38

(3) Annual Benefit. The expected annual acres calculated in (1) are multiplied by the average damage per cleared acre flooded from (2) above to obtain crop damage estimates for with- and without-project conditions. These damage estimates are then adjusted by the appropriate backwater-headwater overlap factors presented in Table 6. The results are presented in Table 8 for various years. These damages and benefits are put on an annual basis using standard discounting procedures as outlined in the introduction. Total annual benefits for the First Phase feature of Alternative 2 using traditional methodologies are estimated at \$3,301,000 at the current (7.375 percent) discount rate. These benefits are also estimated using risk based procedures as required by current guidance.

(4) Risk Analysis. This section provides an estimate of the risk inherent with the economic and hydrologic data used to evaluate the flood damage prevented benefits. It addresses the areas where risk and uncertainty are known to exist so that the economic performance of the project can be expressed in terms of probability distributions. This analysis was performed using a spreadsheet in conjunction with an add-on simulation model entitled @Risk. It incorporates the range (maximum and minimum) of possible values for an input variable in the flood damage calculation, and specifies the statistical distribution of likely outcomes over the chosen range. In the case where a normal distribution is assumed, 68 percent of the occurrences of a particular outcome would fall within (plus or minus) one standard deviation, on either side of the mean, and 95 percent within two standard deviations on either side of the mean. The initial step in constructing an @Risk simulation is to identify the sources of uncertainty. Some sources of risk and uncertainty arise from measurement errors, small sample sizes, estimation and forecasting errors, and modeling errors. The variables chosen and the amounts they are allowed to vary during the simulation are presented in Table 9. All distribution functions are assumed to be normal.

The @Risk simulation was performed utilizing 3,000 iterations, or different combinations, of the chosen variables. The 68 and 95 percent confidence bands around the mean results are plus/minus one and two standard deviations, respectively. An additional step was taken to identify which variable(s) contributed the most to uncertainty. The simulation was run again, varying each variable individually while holding the remaining variables constant. The most important variable was the 1.5-foot variation in stage frequency followed by the 10 percent variation in the stage area relationship. The results of the individual simulations for the First Phase feature of Alternative 2 and their ranking are also presented in Table 9.

AGRICULTURAL INTENSIFICATION BENEFITS.

Flood protection, full or partial, reduces the financial risks involved in farming operations. Such a reduction allows an intensification of farmlands, which results in higher yields and, subsequently greater net returns to land. Intensification benefits result from an intensification of land that is presently being farmed as no conversion from non-farmed lands is expected to take place. These benefits result from a change to a more profitable crop distribution combination and from more intensive farm inputs that provide greater yields on the individual crops. Flood control improvements would permit better use of land protected from frequent flooding.

Table 8
Agricultural Crop Damages and Benefits
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Year	Without-Project	Alternative 2	Benefit
1998	3,380,997	3,239,944	141,053
1999	3,412,037	3,269,690	142,347
2000	3,443,077	3,158,364	284,713
2001	3,474,118	2,852,104	622,014
2002	3,505,158	1,444,946	2,060,212
2003	3,536,198	787,189	2,749,009
2012	3,815,561	849,374	2,966,187
2022	4,125,964	918,467	3,207,497
2032	4,436,367	987,561	3,448,806
2042	4,746,770	1,056,654	3,690,116
2052	5,057,174	1,125,749	3,931,425
Average Annual Equivalent			
Traditional	5,053,683	1,752,930	3,300,753
Risk Based			
Mean	5,074,892	1,767,243	3,307,649
Standard Deviation	1,073,589	373,859	699,731

Table 9
Agricultural Flood Damage Prevented
Results of Risk Analysis, Variables Ranked by Importance
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	Variation	Agricultural Flood Damage Prevented		Rank
		Mean Value	Standard Deviation	
All Variables		3,307,649	699,731	
Stage Frequency	1.5 Feet	3,308,521	668,803	1
Stage Area	10 Percent	3,293,682	165,890	2
Projection Factors	25 Percent	3,293,758	102,439	3
Crop Yields	10 Percent	3,293,785	84,812	4
Crop Prices	15 Percent	3,293,837	79,062	5
Production Costs	5 Percent	3,293,795	46,085	6
Interest Rate	7.125% to 7.625%	3,293,877	1,280	7

a. Increased Net Returns per Acre. The intensification benefits are based on the increase in net returns between with- and without-project conditions and are adjusted to account for the increased residual damage to the intensified practices caused by any remaining flooding. The increase in net productive value per cleared acre after installation of the plan was determined as \$28.49 and \$43.12 (1996 and 2050 conditions respectively). These figures were derived from the data presented in Tables 3 and 4. These practices are based on those used by the area farmers under without-project conditions in the above 3-year flood zone less the below 3-year zone.

b. Acres Intensified. These values were applied to the number of acres to be intensified yielding the basic benefit values. The acres intensified are the cleared acres flooded by the 3-year without-project flood less the cleared acres flooded by the 3-year with-project flood (Table 10).

c. Annual Benefit. The basic benefit values are adjusted downward to account for any increased damage caused by planting higher value crops on those acres flooded after project installation (Table 11) and the backwater-headwater overlap factors presented in Table 6 and discussed previously. The results are presented in Table 12 for various years. These benefits are put

on an annual basis using standard discounting procedures as outlined in the introduction. Total annual benefits for traditional methodologies are estimated at \$1,215,000 at the current (7.375 percent) discount rate. These benefits are also estimated using risk-based procedures as required by current guidance.

Table 10
Area Subject to Intensification
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS

	Three-Year Flood Zone	Three-Year Flood Zone	Area
Item	Without-Project	With-Project	Intensified
Headwater			
St Johns Bayou	3,102	844	2,258
St James Ditch	6,634	0	6,634
Birds Point Levee Ditch	5,732	0	5,732
Backwater			
St Johns Pump Station	18,820	11,248	7,572
New Madrid Pump Station			
Lower New Madrid	4,739	86	4,653
St James Bayou	13,240	2,784	10,456
Total Project Area			
	52,267	14,962	37,305

Table 11
Increased Residual Damage due to Intensified Practices
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels

Stream/Reach	1996 Increased Residual Damage	2050 Increased Residual Damage
Headwater		
St Johns Bayou	0	0
St James Ditch	13,832	20,821
Birds Point Levee Ditch	0	0
Backwater		
St Johns Pump Station	41,134	61,918
New Madrid Pump Station		
Lower New Madrid	0	0
St James Bayou	9,866	14,851

Table 12
Agricultural Intensification Benefits
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Year	Benefit
1998	48,128
1999	48,577
2000	81,489
2001	190,744
2002	816,765
2003	1,010,346
2012	1,091,551
2022	1,181,777
2032	1,272,003
2042	1,362,229
2052	1,452,455
Average Annual Equivalent	
Traditional	1,215,091
Risk Based	
Mean	1,161,584
Standard Deviation	207,746

d. Risk Analysis. This section provides an estimate of the risk inherent with the economic and hydrologic data used to evaluate the agricultural intensification benefits. It addresses the areas where risk and uncertainty are known to exist so that the economic performance of the project can be expressed in terms of probability distributions. This analysis was performed using a spreadsheet in conjunction with a simulation model entitled @Risk. It incorporates the range (maximum and minimum) of possible values for an input variable and specifies the statistical distribution of likely outcomes over the chosen range. In the case where a normal distribution is assumed, 68 percent of the occurrences of a particular outcome would fall within (plus or minus) one standard deviation, on either side of the mean, and 95 percent within two standard deviations on either side of the mean. The variables chosen and the amounts they were allowed to vary are presented in Table 13. All distribution functions are assumed to be normal.

e. The @Risk simulation was performed utilizing 3,000 iterations, or different combinations, of the chosen variables. The 68 and 95 percent confidence bands around the mean results are plus/minus one and two standard deviations, respectively. An additional step was taken to identify which variable(s) contributed the most to uncertainty. The simulation was run again, varying each variable individually while holding the remaining variables constant. The most important variable was the 1.5-foot variation in stage frequency followed by the 15 percent variation in crop prices. The results of the individual simulations and their ranking are presented in Table 13.

Table 13
Agricultural Intensification Benefits
Results of Risk Analysis, Variables Ranked by Importance
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	Variation	Agricultural Flood Damage Prevented		Rank
		Mean Value	Standard Deviation	
All Variables		1,161,584	207,746	
Stage Frequency	1.5 Feet	1,162,201	139,814	1
Crop Prices	15 Percent	1,196,802	127,684	2
Crop Yields	10 Percent	1,196,826	64,087	3
Stage Area	10 Percent	1,197,037	59,774	4
Projection Factors	25 Percent	1,196,974	56,765	5
Production Costs	5 Percent	1,196,876	25,786	6
Interest Rate	7.125% to 7.625%	1,197,044	20,035	7

STREET AND ROAD BENEFITS.

Alternative 4, which limits improvements to the East Prairie, Missouri area is used as the representative plan to describe the methodology used to estimate street and road benefits. East Prairie experiences flooding from St James Ditch and Lateral Number 2 which inundates eastern and western portions of the town. Flooding from St James Ditch is estimated to cover approximately 10 miles of roads in East Prairie. Damage rates per mile from prior Memphis District studies for comparable areas were developed and applied to the inundated roads. The cost per mile was \$73,200 for perpendicular flooding and \$18,300 for parallel flooding. Total damage from St James Ditch by frequency of flood is presented in Table 14.

The center of town is on higher ground and is not subject to flooding from St James Ditch. However, most of the town is subject to minor or nuisance flooding due to interior drainage problems. Local rainfall in the town is routed through underground culverts. These culverts have been neglected and have fallen into disrepair. They can handle rainfall events up to approximately the 10-year flood. Events in excess of the 10-year flood exceed the culvert's capacity and spill out onto the town's streets. This flooding covers approximately 19 miles of East Prairie's roads. The above damage rates were applied to the mileage of inundated roads. The results are also presented in Table 14.

Totaling these two sources yields 29 miles of road flooding and \$1,327,000 of damage. Expected annual damages for existing conditions totaled \$119,000 per year. Damages and benefits under with-project conditions are estimated at \$3,000 and \$116,000, respectively (Table 14).

Table 14
Annual Street and Road Damage and Benefit
East Prairie, Missouri
Alternative 4
(Includes Ring Levee and Interior Drainage Improvements)
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Frequency	Existing Conditions			Alternative 4 plus Interior Drainage Improvements		
	St James Ditch	Interior East Prairie	Damage	St James Ditch	Interior East Prairie	Damage
0.000	458,000	869,000	1,327,000	458,000	0	458,000
0.002	458,000	869,000	1,327,000	458,000	0	458,000
0.010	458,000	869,000	1,327,000	0	0	0
0.040	458,000	869,000	1,327,000	0	0	0
0.100	0	869,000	869,000	0	0	0
0.101	0	0	0	0	0	0
Average Annual Equivalent Values						
Damage			119,000			3,000
Benefit						116,000

RESIDENTIAL AND COMMERCIAL STRUCTURE BENEFITS.

The residential and commercial structures located within East Prairie are subject to the same flood conditions as the streets and roads. They are subject to inundation by both St James Ditch and East Prairie's interior drainage problems. Information on all structures subject to flooding in East Prairie was not available. However, a sample of the affected structures was available from the information developed in the LRR. Information on approximately one-third of affected structures was available. Information for these structures was used as a proxy and applied to all structures subject to inundation by each source. Total structural damages were estimated using damage frequency relationships, which were developed by incorporating the procedures described in the following paragraphs.

The depth of inundation which could be expected from eight floods of various return intervals (annual frequency series 1.01, 2, 5, 25, 100, 500, and SPF) was calculated by comparing the first floor elevation with the water surface elevation for each flood. These depths were incorporated with standard depth-percent damage curves used by the Memphis District to estimate structure and content damages for each flood event. The content value of all residential structures is estimated to represent 50 percent of the structure value. Additionally, floodwater tends to damage lawns and shrubbery encircling structures by removing topsoil and/or depositing silt and debris. This damage (cleanup cost) is assumed to be two percent of the structure's value. Damage due to cleanup cost begin when flood water exceeds the ground elevation and remains constant regardless of further increases in floodwater depth.

Table 15 shows the damage by flood event, annual damage, benefit by flood event, and annual benefits. Annual damage under existing conditions is estimated at \$348,000. Under with-project conditions the damage drops to \$40,000 annually resulting in \$308,000 of annual benefit.

METHODOLOGY USED TO ESTIMATE PROJECT ANNUAL COSTS

The project costs, like the annual benefits, are based on current price levels (October 1996), estimated over a 50-year project life plus the installation period, and discounted to the end of the project installation period using the current Federal discount rate (7.375%). Economic costs associated with the project are initial investment charges, operation and maintenance charges, and replacement charges.

PROJECT FIRST COSTS.

Project costs total \$41,004,000 for the First Phase feature of Alternative 2. These costs do not include all necessary mitigation costs. However, they are suitable for demonstrating the methodology used in calculating the annual interest and sinking fund costs. The mitigation costs for Alternative 2 would include those for Alternative 3-1 plus costs for items that were not practical for construction such as the 200-foot bottom-width channel on St Johns Bayou and the reach of St James Ditch that contained the State of Missouri listed species. Mitigation costs were developed for all practical and/or economically feasible projects (Alternatives 3, 5, 7-2, and 7-3) and are included in the benefit to cost analysis. The largest part of the cost is for construction which includes the both pumping stations and all channel improvements. The second largest item is for engineering and design, followed by relocations, construction management, and lands. These costs are based on October 1996 price levels and are assumed to be end of year expenditures for discounting purposes.

ANNUAL INTEREST AND SINKING FUND COSTS.

The annual interest and sinking fund costs are summarized in Table 16. They are based on a reference point at the beginning of year 2003 (end of year 2002), the current discount rate of 7.375 percent, and a 50-year period of analysis. Annual interest charges are \$3,564,000 and annual sinking fund charges are \$104,000. Total annual interest and sinking fund costs are \$3,668,000 for the First Phase feature of Alternative 2.

Table 15
Annual Residential and Commercial Structure Damage and Benefit
East Prairie, Missouri
Alternative 4
(Includes Ring Levee and Interior Drainage Improvements)
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Frequency	Existing Conditions			Alternative 4 plus Interior Drainage Improvements		
	St James Ditch	Interior East Prairie	Damage	St James Ditch	Interior East Prairie	Damage
0.000	4,744,605	2,091,690	6,836,295	4,744,605	0	4,744,605
0.002	4,744,605	2,091,690	6,836,295	4,744,605	0	4,744,605
0.010	3,495,267	2,091,690	5,586,957	187,172	0	187,172
0.040	1,357,481	1,948,340	3,305,821	187,172	0	187,172
0.100	12,512	1,661,640	1,674,152	0	0	0
0.101	12,387	0	12,387	0	0	0
0.200	0	0	0	0	0	0
Average Annual Equivalent Values						
Damage			348,000			40,000
Benefit						308,000

Table 16
Annual Investment Cost
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Year	n	Investment Cost	Present Value Factor	Present Value of Investment Cost
1997	-5	919,000	1.42730	1,311,689
1998	-4	3,857,000	1.32927	5,126,994
1999	-3	13,149,000	1.23797	16,278,067
2000	-2	16,761,000	1.15294	19,324,427
2001	-1	9,620,000	1.07375	10,329,475
2002	0	1,360,000	1.00000	1,360,000
Total		45,666,000		53,730,652
Annual Interest			0.07375	3,962,000
Annual Sinking Fund			0.00216	116,000
Total Interest and Sinking Fund			0.07591	4,078,000

ANNUAL OPERATION, MAINTENANCE, AND REPLACEMENT COSTS.

a. Channel Items. The estimated costs of channel maintenance and replacements for the First Phase feature of Alternative 2 are presented in Table 17. These expenditures reflect previous experience with similar projects from this region. Brush-kill is required at 4-year intervals. Channel maintenance is required at 20-year intervals. Bridge replacements are required every 30 to 50 years as dictated by the life of the new bridges. Total maintenance and replacement cost is approximately \$20,000.

b. Pumping Stations. Operation, maintenance, and replacement costs associated with the pumping stations are estimated at \$152,000 annually (Table 18). They include electricity and labor costs, replacement of pump impellers every 40 years, gear reducers every 30 years, electric motor stators and motor control centers every 35 years, and roof replacement at 20 year intervals.

Table 17
Annual Operation, Maintenance, and Replacement Costs for Channel Items
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	Cost				Annual Cost			
	Brushkill	Cleanout	Replacements		Brushkill	Cleanout	Replacements	Total
St John's Bayou								
Total	4,500	24,750	221,000	275,000	1,253	695	3,949	6,000
Miles	4.50	4.50						
Per Mile	1,000	5,500						
Frequency	4 Years	20 Years	30 Years	50 Years				
St James Ditch								
Total	10,800	59,400	486,000	125,000	2,586	1,448	5,339	9,000
Miles	10.80	10.80						
Per Mile	1,000	5,500						
Frequency	4 Years	20 Years	30 Years	50 Years				
Birds Point Levee Ditch								
Total	12,400	68,200			3,214	1,785		5,000
Miles	12.40	12.40						
Per Mile	1,000	5,500						
Frequency	4 Years	20 Years						

Table 18
Annual Operation, Maintenance, and Replacement Costs for Pump Stations
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	New Madrid Station			St Johns Station		
	Interval	Replacement Cost	Annual Cost	Interval	Replacement Cost	Annual Cost
Replacement Cost and Interval						
Pump Impellers	40	193,200	914	40	165,131	728
Gear Reducer	30	124,829	843	30	70,771	636
Electric Motor Stators	35	80,681	778	35	72,000	453
Motor Control Center	35	226,873	1,533	35	164,960	1,038
Roof	20	28,224	687	20	22,050	502
Maintenance Cost						
Roof	7	21,393	2,619	7	15,669	1,790
Estimated Maintenance	1	12,267	12,267	1	12,267	12,267
Operating Cost						
Labor			15,200			15,200
Energy Charges			39,000			39,000
Facility Charge			3,000			3,000
Total Annual Costs			77,000			75,000

SUMMARY OF PLANS CARRIED INTO DETAILED ECONOMIC ANALYSIS

ALTERNATIVE 2.

Alternative 2 includes a 1,500 foot levee closure and structure at the south end of the New Madrid Floodway which will prevent backwater flooding from the Mississippi River and two pumping stations, one in the New Madrid Floodway basin and the other in the St Johns Bayou basin.

Also included is channel enlargement on St Johns Bayou, Birds Point Levee Ditch, and St James Ditch, which is designed to drain the area in the vicinity of East Prairie Missouri. The closure is a feature of the Mississippi River Levees (MRL) project and as such has a project discount rate of 2.5%. All other features use a discount rate of 7.375%.

a. Annual Benefit. Total annual benefits for the MRL feature of Alternative 2 are presented in Table 19. Agricultural benefits account for 91 percent of the feature's benefits. Inundation reduction benefits comprise 71 percent of the benefits followed by intensification at 29 percent. The

benefits of the First Phase feature are presented in Table 20. The agricultural benefits of this feature account for 90 percent of the benefits. Inundation reduction benefits comprise 76 percent of the project benefits followed by intensification at 23 percent. The remaining 1 percent is composed of betterment and advanced replacement benefits, which are due to improving or replacing area bridges during construction.

Table 19
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
MRL Feature of Alternatives 2, 3, and 7
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 2.5%)

Alternative	First Cost	Annual Benefit	Annual Cost	Excess Benefit	Benefit to Cost Ratio
2	39,153,000	1,279,000	1,166,000	113,000	1.1
3-1	39,153,000	1,279,000	1,166,000	113,000	1.1
3-2	42,021,000	1,263,000	1,293,000	-30,000	0.98
3-3	45,866,000	1,013,000	1,447,000	-434,000	0.7
7-2	44,882,000	873,000	1,447,000	-574,000	0.6
7-3	38,795,000	342,000	1,293,000	-951,000	0.3

Table 20
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
First Phase Feature of Alternative 2
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	\$
Annual Benefit	
Agricultural Inundation Reduction	3,308,000
Agricultural Intensification	1,162,000
Streets and Roads	455,000
Advanced Replacements	52,000
Betterments	4,000
Total	4,981,000
First Cost ^{1/}	47,788,000
Annual Cost	
Interest	3,962,000
Sinking Fund	116,000
Operation Maintenance and Replacement	172,000
Total	4,250,000
Excess Benefits	731,000
Benefit-Cost Ratio	1.2
^{1/} Does not include all mitigation costs. Excludes mitigation costs for the reach of of St James Ditch containing the State of Missouri listed endangered species.	

b. Annual Cost. Annual costs for the MRL feature of Alternative 2 are also presented in Table 19. The annual costs for the First Phase feature are presented in Table 20. Annual interest and sinking fund costs reflecting the financing costs of the project account for 96 percent of the First Phase feature's cost. The remaining 4 percent is operation and maintenance that is primarily operation and maintenance of the two pumping stations and associated facilities.

c. Summary. Alternative 2 does not include all of the environmental effects or the necessary cost of mitigating for potential environmental effects associated with the First Phase feature. It includes the mitigation for the pumping station but does not include the mitigation for work in the upper St James Ditch portion of the project where an endangered species has been found. This area is avoided in Alternative 3.

ALTERNATIVE 3.

Alternative 3-1.A is a refinement of Alternative 2 above, which incorporates measures designed to avoid some of the detrimental environmental effects associated with Alternative 2. Included in these features are downsizing the channel along St Johns Bayou and shortening the work reach on St James Ditch to avoid the potential endangered species problem listed above. Included in Alternative 3A are two additional MRL feature locations (3-2.A and 3-3.A). The benefit and cost data for the additional MRL feature locations are also presented in Table 19. Alternatives 3-1.A, 3-2.A, and 3-3.A were further analyzed for two different start-stop pump/gate closure scenarios. Alternatives 3-1.B, 3-2.B and 3-3.B keep the gates open and pump off until an elevation of 284.4 is reached. Alternatives 3-1.C, 3-2.C and 3-3.C use an elevation of 284.4 for two out of three years with an elevation of 288.0 every third year.

a. Annual Benefit. Annual benefits for the First Phase feature of all sub-options of Alternative 3 are presented in Table 21. Like this feature of Alternative 2, the majority of benefits are agricultural and inundation reduction.

b. Annual Cost. The annual costs for the First Phase feature of all sub-options of Alternative 3 are also presented in Table 21. These costs include Mitigation costs.

c. Summary. The First Phase features of all sub-options of Alternative 3 are economically feasible as shown in Table 21. However, the MRL Feature is economically feasible for only Alternatives 3-1.A, 3-1.B, and 3-1.C.

ALTERNATIVE 4.

Alternative 4 includes a ring levee around the town of East Prairie, Missouri to protect it from headwater flooding associated with St James Ditch and Lateral 2. Detailed analysis associated with development of this alternative during scoping revealed that additional improvements within the town could be warranted to solve flooding associated with inadequate storm sewer problems. This work is an additional feature, which could be considered in conjunction with both the ring levee and the channel work in Alternative 3. A summary of the benefits and costs of Alternative 4 are presented in Table 22. This table reveals that none of the features of Alternative 4, either individually or in combination, is economically justified.

The interior improvements were analyzed in conjunction with the St James Ditch improvements of Alternative 3 to see if they would possibly be feasible as part of Alternative 3. The results of this analysis and a comparison with Alternative 4 are presented in Table 23. The combination of St James Ditch improvements and the interior drainage improvements is economically justified. However, the interior ditch work is not incrementally justified at this time.

Table 21
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
First Phase Feature of Alternative 3
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Alternative	First Cost	Annual Benefit	Annual Cost	Excess Benefit	Benefit to Cost Ratio
3-1.A	43,936,000	4,674,000	3,948,000	726,000	1.2
3-1.B	41,179,000	4,567,000	3,795,000	772,000	1.2
3-1.C	39,644,000	4,121,000	3,710,000	411,000	1.1
3-2.A	43,959,000	4,690,000	3,956,000	734,000	1.2
3-2.B	41,257,000	4,630,000	3,806,000	824,000	1.2
3-2.C	39,752,000	4,216,000	3,722,000	494,000	1.1
3-3.A	43,732,000	4,758,000	3,959,000	799,000	1.2
3-3.B	40,999,000	4,789,000	3,808,000	981,000	1.3
3-3.C	39,483,000	4,477,000	3,723,000	754,000	1.2

Table 22
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
Alternative 4, Improvements to the East Prairie, Missouri Area
St. Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels, 7.375% Discount Rate

Item	Ring Levee	Interior Drainage Ditches	Combination of Ring Levee and Interior Drainage Ditches
Annual Benefit			
Urban	117,000	191,000	308,000
Streets and Roads	29,000	87,000	116,000
Advanced Replacements		5,000	
Betterments		5,000	
Total	146,000	288,000	424,000
First Cost	4,132,000	7,564,000	11,977,000
Annual Cost			
Interest	316,000	578,000	916,000
Sinking Fund	9,000	17,000	27,000
Operation, Maintenance and Replacement	1/	1,000	1/
Total	325,000	596,000	943,000
Excess Benefit	-179,000	-308,000	-519,000
Benefit-Cost Ratio	0.45	0.48	0.45

1/ Operation, maintenance, and replacement costs not estimated since the benefit-to-cost ratio is less than unity.

Table 23
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
Improvements to the East Prairie, Missouri Area
Comparison of Alternative 4 and the East Prairie Segment of Alternative 3
St. Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels, 7.375% Discount Rate

Item	Alternative 3			Alternative 4		
	St. James Ditch Channel Improvements	Interior Drainage Ditches	Total	Ring Levee	Interior Drainage Ditches	Total
Annual Benefit						
Agricultural Inundation						
Reduction	214,000		214,000			
Agricultural Intensification	131,000		131,000			
Urban	146,000	191,000	337,000	117,000	191,000	308,000
Streets and Roads	233,000	87,000	320,000	29,000	87,000	116,000
Advanced Replacements	21,000	5,000	26,000		5,000	
Betterments	1,000	5,000	6,000		5,000	
Total	746,000	288,000	1,034,000	146,000	288,000	424,000
					7,564,000	
First Cost	3,277,000	7,564,000	10,841,000	4,132,000		11,977,000
Annual Cost						
Interest	255,000	578,000	833,000	316,000	578,000	916,000
Sinking Fund	7,000	17,000	24,000	9,000	17,000	27,000
Operation, Maintenance and Replacement	6,000	1,000	7,000	<u>1/</u>	1,000	<u>1/</u>
Total	268,000	596,000	864,000	325,000	596,000	943,000
					-	
Excess Benefit	478,000	-308,000	170,000	-179,000	308,000	-519,000
Benefit-Cost Ratio	2.8	0.48	1.2	0.45	0.48	0.45

1/ Operation, maintenance, and replacement costs not estimated since the benefit-to-cost ratio is less than unity.

ALTERNATIVE 5.

Alternative 5 consists of the St Johns Bayou Basin portion of Alternative 3. It includes the St Johns Bayou pumping station and channel work on St Johns Bayou, Birds Point Levee Ditch, and St James Ditch. The benefits and costs for Alternative 5 are presented in Table 24. This alternative is economically justified with \$203,000 in excess benefits and a benefit-to-cost ratio of 1.08. However, construction of this alternative by itself would leave the most economically sound portion of Alternative 3-1B (overall project) un-built. Table 25 shows that the un-built First Phase feature of the project would contribute an additional \$569,000 of net (NED) benefits to the nation's economy along with the \$113,000 of excess benefits associated with the MRL feature (Table 19). It would also have a benefit-to-cost ratio of 1.4 to 1. Additionally, Alternative 5 would not fully meet the goals of the East Prairie Enterprise Community (EC). Its goal is to provide economic development opportunities to the East Prairie area. Leaving the New Madrid Floodway portion of the project un-built would cause the EC to forego substantial economic opportunities for their community. The additional annual benefit would flow through their community many times over creating a significant multiplier effect and create many new employment opportunities and greatly increase the quality of life in the East Prairie area.

ALTERNATIVE 7.

Alternative 7-1 is an alternate levee alignment located further inside the New Madrid Floodway, starting from Tenmile Pond and extending along St James Bayou to tie into the Frontline Levee southeast of Big Oak Tree State Park. This alignment was studied in detail in the St Johns Bayou and New Madrid Floodway, Missouri, Phase I GDM dated July 1980. This alignment also included a pump station to remove any impounded rainfall collecting behind the proposed levee. Four pump station sizes were analyzed in the Phase I GDM. These were sized at 250, 500, 750, and 1,000 cubic feet per minute (CFS). The costs and benefits for these proposed features were indexed to current price levels (October 1996 for consistency with the other alternatives) to assess the effects of an alignment in the upper floodway. Alternatives 7-2 and 7-3 are two additional levee closure alternatives north of the locations analyzed in Alternative 3. The results for the MRL feature of these alternatives are presented in Table 19. The results for the First Phase Feature of these alternatives are presented in Table 26.

Table 24
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
Alternative 5
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	\$
Annual Benefit	
Agricultural Inundation Reduction	1,706,000
Agricultural Intensification	553,000
Streets and Roads	392,000
Advanced Replacements	52,000
Betterments	4,000
Total	2,707,000
First Cost	28,487,000
Annual Cost	
Interest	2,344,000
Sinking Fund	68,000
Operation Maintenance and Replacement	92,000
Total	2,504,000
Excess Benefit	203,000
Benefit-Cost Ratios	1.08

Table 25
Comparison of Alternatives 5 With the First Phase Portion of Alternative 3-1B
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	Alternative 3 <u>1</u> /	Alternative 5	Difference
Annual Benefit			
Agricultural Inundation Reduction	3,018,000	1,706,000	1,312,000
Agricultural Intensification	1,038,000	553,000	485,000
Streets and Roads	455,000	392,000	63,000
Advanced Replacements	52,000	52,000	0
Betterments	4,000	4,000	0
Total	4,567,000	2,707,000	1,860,000
First Cost	41,179,000	28,487,000	12,692,000
Annual Cost			
Interest	3,523,000	2,344,000	1,179,000
Sinking Fund	103,000	68,000	35,000
Operation Maintenance and Replacement	169,000	92,000	77,000
Total	3,795,000	2,504,000	1,291,000
Excess Benefit	772,000	203,000	569,000
Benefit-Cost Ratios	1.2	1.08	1.4

1/ First Phase portion of Alternative 3-1B, excludes MRL portion of project.

Table 26
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
Alternative 7, Excludes MRL Feature
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels, 7.375% Discount Rate

Alternative/Feature	First Cost	Annual Benefit	Annual Cost	Excess Benefit	Benefit to Cost Ratio
7-1					
New Madrid Floodway <u>1/</u>					
250 CFS Pump Station	15,193,000	-807,000	1,234,000	-2,041,000	--
500 CFS Pump Station	17,300,000	-233,000	1,407,000	-1,640,000	--
750 CFS Pump Station	19,989,000	-132,000	1,533,000	-1,665,000	--
1,000 CFS Pump Station	20,443,000	-51,000	1,651,000	-1,702,000	--
St Johns Bayou Basin	28,487,000	2,707,000	2,504,000	203,000	1.1
7-2					
New Madrid Floodway	15,024,000	1,885,000	1,435,000	450,000	1.3
St Johns Bayou Basin	28,487,000	2,707,000	2,504,000	203,000	1.1
Subtotal	43,511,000	4,592,000	3,939,000	653,000	1.2
7-3					
New Madrid Floodway	14,899,000	1,909,000	1,432,000	477,000	1.3
St Johns Bayou Basin	28,487,000	2,707,000	2,504,000	203,000	1.1
Subtotal	43,386,000	4,616,000	3,936,000	680,000	1.2

1/ Negative numbers in annual benefit row actually indicate induced flood damages. Benefit-to-cost ratio is not applicable since this alternative produces no benefit.

Alternative 7-1 was found to cause considerable problems by impounding significant amounts of captured rainfall behind the proposed levee on lands that were not previously subject to frequent flooding. The lands protected by this alignment are subject to backwater flooding from the Mississippi River but at a frequency much less than the expected frequency of the impounded rainfall. All of the four pump sizes were not large enough to compensate for the impounded rainfall. This levee alignment in combination with each pump size considered actually induced significant flood damages. As part of this study, a trend line analysis was performed by graphically analyzing the induced damages versus the CFS capacity of the proposed pumping stations. It was found that a pump size somewhere between 1,000 and 1,250 CFS would probably be required to offset any induced flood damages and maintain current conditions. A similar analysis of indexed levee and pump station sizes revealed that this alternative would cost in the range of \$20 to \$22 million dollars. Because of the absence of any tangible benefit, this alternative was not considered further.

While addressing this alternative and searching for other alternate levee sites, it was quickly seen that moving the levee further up into Floodway would reduce benefits while substantially increasing costs. The benefits are reduced by decreasing the size of the benefited area and by

moving the project's sump area further up into the Floodway. Moving the sump area causes an increase in the frequency of flooding on the lands within the new sump area. This increase in flood frequency will cause a corresponding increase in annual damage on these lands that previously received less damage. The project's costs would be increased substantially by increasing the length of the closure levee. Currently the closure levee is only 1,500 feet. This is shown in Alternatives 7-2 and 7-3 presented in Table 26. The MRL feature of alternatives 7-2 and 7-3 are not economically justified.

ALTERNATIVE 9.

Alternative 9 is a combination of non-structural measures. These include floodplain evacuation and relocation of residents, flood proofing, food easements, restrictive easements, and a conversion of agricultural lands subject to frequent flooding to uses not significantly damaged by repeated flooding. Non-structural alternatives do not provide flood control in that they do not change existing flood conditions, areas flooded, or duration of flooding. Instead, they potentially reduce flood damages by changing the character or nature of the development within the floodplain. These alternatives are presented in the following two sections, the first for the urbanized area of East Prairie and the second for the rural agricultural area surrounding East Prairie.

a. East Prairie, Missouri Urban Area.

(1) Evacuation and Relocation of Residents. The first nonstructural alternative considered was floodplain evacuation and relocation of area residents. It was only considered for the urbanized area in and around East Prairie, Missouri since the rural, frequently flooded areas such as the lower St Johns Bayou Basin and the New Madrid Floodway are mostly unpopulated. An alternative such as this was considered in the Phase I GDM for nearby Sikeston, Missouri. The results of the Phase I study indicated that it was not economically feasible. In spite of this, it was again investigated to see if it could possibly help mitigate some of the effects of flooding in East Prairie. This first step in an evacuation and relocation alternative is to find a suitable site to relocate affected structures and residents. This type alternative is effective only if a suitable nearby site can be found. It was determined early in the investigation that East Prairie, Missouri is located on one of the highest sites available in the nearby vicinity. No suitable nearby sites were found. Because of the considerable expense, great disruption to the social well being of the community and lack of suitable sites, this alternative was eliminated from further study.

(2) Flood Proofing. Flood proofing measures include those, which protect the structure and its contents by excluding water, i.e., closures and seals, raising the structure, and perimeter barriers. These measures reduce damage at each stage of flooding until the design level is exceeded. Flood proofing also includes actions which modify the use of a structure to reduce damage susceptibility, i.e., rearranging the contents of a structure, restricting use of lower floors and protecting damageable contents such as appliances and utilities. Both types of flood proofing require site and structure specific analyses. All structures within the floodplain need to be examined and specific measures evaluated. Flood proofing does not alleviate the significant street and road flooding in East Prairie that cause frequent problems with access into and out of the community during flood times. However, flood proofing may hold potential as a partial remedy if a structural

solution cannot be implemented. It may also offer some relief from the interior drainage problems not addressed by the channel improvement on St James Ditch.

(3) Restrictions on Future Development. Such restrictions do not help existing flood problems, but they can greatly assist in keeping situations in current problem areas from worsening and in avoiding any future problem areas. East Prairie already places significant restrictions on future development. It complies with FEMA guidelines and requires future development to be at or above the 100-year flood level. Because of this, it was determined that little could be gained from additional restrictions on future development.

b. Rural Agricultural Area. The non-structural measures evaluated for the rural agricultural area do not provide flood control in that they do not change existing flood frequency, elevation, or duration. Instead, they are intended to reduce flood damages by changing the character or nature of the development within the floodplain. Non-structural alternatives investigated for the rural agricultural area include: Flood Easements, Restrictive Easements, and Changes in Land Use.

(1) Flood Easements. Flood easements could be purchased on currently affected lands to compensate the landowners for the effects of frequent flooding. The fallacy of flood easements is that they do not actually reduce flood damage, increase efficiency, or produce additional income. The flood conditions and the type of development within the floodplain remain unchanged. Since none of these will occur, no contribution or benefit to the national economy will be realized. Because of this, it was determined that flood easements are not economically feasible since they produce no economic benefit.

(2) Restrictive Easements. A restrictive easement would allow the land use to remain agricultural but could produce benefits to the national economy by causing a shift to crops less susceptible to flood damage or by changing crops to shorter maturing crops which could possibly avoid the spring or fall flood seasons. The area's farmers are presently planting soybeans in the most frequently flooded areas. Soybeans is the crop that is least subject to flood damage since it is the cheapest crop to grow, requires the least amount of inputs, and has the shortest growing season of any major field crop. Since no better alternative crops are currently available that have the potential to reduce flood damages more than soybeans, this was not considered to be a viable option.

(3) Change in Land Use. This part of Alternative 9 would convert frequently flooded cropland in both basins to a more flood tolerant land use. It would reduce flood damages by changing the existing land use but again would not provide any flood protection. The primary means to change land use in the area is to either directly purchase affected lands or to offer economic incentives for the landowners to shift to other uses such as forestry. Alternative 8 looked at how programs such as the Wetland Reserve Program (WRP) could be used to entice area landowners to convert forestry practices. The WRP has been in existence for many years with few, if any, taking advantage of the program. This program is not currently being utilized and there presently is no indication from the local landowners that it will be used in the future. Absent additional incentives for the local landowners to participate, this alternative could not be implemented. This part of Alternative 9 looks at the economic viability of outright purchasing and reforesting the most frequently flooded areas. It was analyzed under two scenarios. The first is a traditional analysis that

treated the benefits and costs of woodlands (i.e., hunting and timber production from the annual benefits and woodland costs from the annual costs) as financial costs and benefits and excluded them from the economic analysis. The second is a newer, nontraditional, analysis that reflects wording in the Water Resources Development Act of 1999 that treated the woodland benefits and costs as economic benefits and costs and included them in the economic analysis.

(a.) Traditional Analysis. The traditional benefit of a non-structural alternative, which alters a floodplain's activities or development, is the new value of the floodplain caused by the alteration (i.e. location benefit). There is no benefit taken for reduction in flood damage because it is assumed that expected flood losses, for the most part, lower the value of the property in its current use. If effective, the non-structural alternative will raise the property's value. This new value is then used as the alternative's benefit. Since the flood damages are already reflected in the initial lower property values used to estimate the project's costs, it would be double counting to include the costs of the physical flood damage as a project's benefit under this type of analysis.

Location benefits are critical to the economic justification of a non-structural project. It is unlikely that a non-structural project can be justified if the property does not have considerable value in its new use. A location benefit is measured by the value of the floodplain in its new use. Unlike location benefits for structural projects, the value of the property in its old use is not subtracted because that value has already been considered in the purchase price of the property in its old use. The location benefit can be determined by estimating the net income of the projected activity. The problem with a non-structural alternative for the agricultural area in both basins is that the agricultural lands are already in their highest and best economic use, the production of crops. The income from cropland exceeds the income of the next best economic use, woodlands. This is evidenced by the landowners nonparticipation in government subsidized reforestation programs such as the Wetland Reserve Program. It is further evidenced by the market prices of cropland and woodland in the area. The Economic Rent Theory of land valuation recognizes that the capitalized value of the income stream produced on land is reflected in its price. Woodland prices are significantly lower than cropland prices reflecting the lower income streams.

The traditional analysis found this alternative not to be justified. It yields annual economic benefits and costs of \$735,000 and \$1,993,000, respectively, with a benefit-to-cost ratio of 0.37 to 1. The estimated financial cost of the project is \$41,833,000. The primary reason that a reforestation alternative is not feasible is that the area's farmland is not marginal, but is prime farmland. The income from producing crops on this prime farmland far outweighs the income produced from producing wood products. This is reflected by the values of frequently flooded cropland and woodland in the project area. The area's cleared farmland sells for approximately \$1,600 per acre while woodland sells for around \$700 per acre. A landowner would face a \$900 per acre reduction in value if he converts his cropland to woodland. This reveals that this alternative would cause a net loss to the Nation's economy. The results of this analysis are presented in Table 27.

(b.) Non-Structural Alternatives under Sections 214 and 222 of WRDA 1999. The Water Resources Development Act of 1999 (WRDA99) contains two sections that potentially affect this non-structural alternative. They are Sections 214 and 222. Section 214 is the Flood

Mitigation and Riverine Restoration Pilot Program. It is a program whereby flood damages can be reduced by restoring the natural functions and values of a river. These projects can be built provided:

1. They will significantly reduce potential flood damages.
2. They will improve the quality of the environment.
3. They are economically justified considering all costs and beneficial outputs of the project.

Table 27
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
Alternative 9, Change in Land Use (Reforestation)
Reflecting Sections 214 and 222 of WRDA 1999
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels, 7.375% Discount Rate

Item	Excluding Woodland Costs and Benefits <u>1/</u>	Including Woodland Costs and Benefits <u>2/</u>
Acreage	21,160	21,160
Financial Cost	41,833,000	41,833,000
Economic Cost	27,021,000	41,833,000
Annual Benefits		
Flood Damage Prevented	735,000	735,000
Increased Hunting Income		58,000
Woodland Income		397,000
Total	735,000	1,190,000
Annual Cost	1,993,000	3,085,000
Excess Benefits	-1,258,000	-1,895,000
BCR	0.37	0.39

1/ Woodland costs treated as financial costs, not economic costs. As such benefits associated with woodlands are also treated as financial benefits.

2/ Woodland costs and benefits treated as economic costs and benefits.

Also Section 222 allows the estimation of flood control benefits similar to structural projects. Traditionally, the benefits of a nonstructural were estimated using a land valuation methodology. Under Section 222 the benefits can be comprised of the flood losses or flood damages avoided. In light of this recent development, the Land Use Change component of Alternative 9 was investigated further. The cost of purchasing the 3-year floodplain in the New Madrid Floodway was analyzed under this proposed methodology to see if a different result would be reached than under a traditional analysis. The 3-year floodplain was chosen because this is the area where most of a project's benefits typically accrue. The results of this analysis are presented in Table 27.

This portion of Alternative 9 treated the woodland benefits and costs as economic benefits and costs and included them in the economic analysis. Alternative 9 was not justified under this scenario either. It yielded annual economic benefits of \$1,190,000 and annual costs of \$3,085,000 with a benefit-to-cost ratio of 0.39 to 1. The estimated financial cost of the project is \$41,833,000.

(c.) Summary. Under both scenarios, the purchase and reforestation of the most frequently inundated croplands within the project area is not economically feasible. Further, the rural non-structural measures would require significant expenditures equivalent to or greater than any of the structural alternatives previously considered. Additional studies may be able to identify smaller non-structural measures that could be implementable in the urban areas.

NED PLAN.

A comparison of the First Phase of all alternatives is presented in Table 28. The MRL feature is presented in Table 19. The MRL feature is optimized based on the "grandfathered" interest rate of 2.5%. Table 19 shows that Alternative 3-1 is the optimum or NED levee closure location. After the NED closure location was identified, it then becomes possible to identify the NED First Phase feature. The First Phase features are optimized on a discount rate of 7.375%. Alternative 3-1.B contains the NED First Phase feature. Table 29 presents the benefit and cost data for Alternative 3-1.B, the NED plan.

Table 28
Comparison of Alternatives
First Phase Portion of Project Only
St Johns Bayou and New Madrid Floodway, EIS
October 1996 Price Levels, 7.375% Discount Rate

Alternative	First Cost	Annual Benefit	Annual Cost	Excess Benefit	Benefit-to-Cost Ratio
Alternative 2 <u>1/</u>	47,788,000	4,981,000	4,250,000	731,000	1.2
Alternative 3					
3-1.A	43,936,000	4,674,000	3,948,000	726,000	1.2
3-1.B <u>2/</u>	41,179,000	4,567,000	3,795,000	772,000	1.2
3-1.C	39,644,000	4,121,000	3,710,000	411,000	1.1
3-2.A	43,959,000	4,690,000	3,956,000	734,000	1.2
3-2.B	41,257,000	4,630,000	3,806,000	824,000	1.2
3-2.C	39,752,000	4,216,000	3,722,000	494,000	1.1
3-3.A	43,732,000	4,758,000	3,959,000	799,000	1.2
3-3.B	40,999,000	4,789,000	3,808,000	981,000	1.3
3-3.C	39,483,000	4,477,000	3,723,000	754,000	1.2
Alternative 4					
Ring Levee	4,132,000	146,000	325,000	-179,000	0.45
Interior Drainage Ditches	7,564,000	288,000	596,000	-308,000	0.48
Combination Ring Levee and Interior Ditches	11,977,000	424,000	943,000	-519,000	0.45
Alternative 5	28,487,000	2,707,000	2,504,000	203,000	1.1
Alternative 7					
7-1					
St Johns Bayou Basin	28,487,000	2,707,000	2,504,000	203,000	1.1
New Madrid Floodway Basin					
250 CFS Pump Station	15,193,000	-807,000	1,234,000	-2,041,000	3/
500 CFS Pump Station	17,300,000	-233,000	1,407,000	-1,640,000	3/
750 CFS Pump Station	19,989,000	-132,000	1,533,000	-1,665,000	3/
1,000 CFS Pump Station	20,443,000	-51,000	1,651,000	-1,702,000	3/
7-2	43,511,000	4,592,000	3,939,000	653,000	1.2
7-3	43,386,000	4,616,000	3,936,000	680,000	1.2
Alternative 9					
Woodland Costs Treated as Financial Costs	41,833,000	735,000	1,993,000	-1,258,000	0.37
Woodland Costs Treated as Economic Costs	41,833,000	1,190,000	3,085,000	-1,895,000	0.39

1/ Excludes Mitigation costs for upper St James Ditch.

2/ NED Plan.

3/ Benefit-to-cost ratio is not applicable since this alternative produces no benefit. Negative numbers in annual benefit column actually indicate induced flood damages.

Table 29
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
NED Plan, Alternative 3-1.B
St Johns Bayou and New Madrid Floodway, EIS
(October 1996 Price Levels, 7.375%)

Item	MRL Feature @ 2.5%	First Phase Feature @ 7.375%		
		New Madrid Floodway	St Johns Bayou Basin	Total
Annual Benefit				
Agricultural Inundation Reduction	622,000	1,312,000	1,706,000	3,018,000
Agricultural Intensification	436,000	485,000	553,000	1,038,000
Streets and Roads	131,000	63,000	392,000	455,000
Advanced Replacements			52,000	52,000
Betterments			4,000	4,000
Total	1,189,000	1,860,000	2,707,000	4,567,000
First Cost	36,583,000	12,692,000	28,487,000	41,179,000
Annual Cost				
Interest	763,000	1,179,000	2,344,000	3,523,000
Sinking Fund	313,000	35,000	68,000	103,000
Operation Maintenance and Replacement		77,000	92,000	169,000
Total	1,076,000	1,291,000	2,504,000	3,795,000
Excess Benefits	113,000	569,000	203,000	772,000
Benefit-Cost Ratio	1.1	1.4	1.08	1.2

NED PLAN AT CURRENT PRICE LEVEL AND INTEREST RATE

The NED plan was analyzed at the current discount rate of 6.125% and at current (2002) price levels. The results are presented in Table 30. In the New Madrid Basin, the MRL Closure was not economically justified on a standalone basis with a benefit-to-cost ratio of 0.8 to 1. However, the pumping station had an incremental benefit-to-cost ratio of 1.6 to 1. When these two items are combined their benefit-to-cost ratio is 1.07 to 1. The St Johns Basin items combined have a benefit-to-cost ratio of 1.3 at current price levels and the current discount rate. Overall the total project has a benefit-to-cost ratio of 1.15 to 1.

Table 30
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratio
NED Plan, Alternative 3-1.B
St Johns Bayou and New Madrid Floodway, EIS
October 2002 Price Levels, 6.125%

Item	New Madrid Floodway Basin			St Johns Bayou Basin	Total Project
	Closure	Pumping Station	Total		
Annual Benefit					
Inundation Reduction	940	1,294	2,234	1,683	3,917
Intensification	871	611	1,482	697	2,179
Streets and Roads	147	63	210	413	623
Advanced Replacements				55	55
Betterments				4	4
Fish & Wildlife Preservation	165				165
Total	2,123	1,968	3,926	2,851	6,942
First Cost	44,783	14,647	56,860	30,012	89,442
Annual Cost					
Interest	2,471	1,096	3,410	2,000	5,567
Sinking Fund	133	59	184	108	300
Operation Maintenance and Replacement		90	90	100	190
Total	2,604	1,245	3,684	2,208	6,057
Excess Benefit	-481	723	242	643	885
Benefit-Cost Ratios	0.8	1.6	1.07	1.3	1.15

SOCIOECONOMICS

INTRODUCTION

The President's designation of the East Prairie, Missouri as an Enterprise Community provided the momentum to implement the First Phase of the St. Johns Bayou and New Madrid Floodway Project. The goal behind the Administration's Enterprise Community designation to create self sustaining long term economic development in areas of pervasive poverty, unemployment, and general distress through the development and implementation of strategic plans that allow such areas to reach their full economic potential. The East Prairie Enterprise Community (EC) views the St. Johns Bayou-New Madrid Floodway project as the first step it must take to implement an array of economic development and quality of life initiatives in East Prairie. The EC recognizes that this project in itself will not solve its problems and generate economic prosperity. However, it will significantly reduce the flooding problem that has prevented the EC from taking the necessary actions to achieve economic betterment. The EC designation has proven to be a catalyst for forging a diverse coalition of local communities, agencies, and levee districts in direct support to the project.

In order to implement the First Phase of the St. Johns Bayou and New Madrid Floodway Project (First Phase Project), a gap in the mainline Mississippi River levees has to be closed. This gap at the lower end of the Birds Point-New Madrid Floodway has presently not been constructed due to the reluctance of local interests in providing the necessary rights-of-way. Local interests are concerned over the evacuation of interior drainage. However, with the addition of the New Madrid Pumping Station as part of the First Phase Project, the local concerns are addressed and will allow the project to be implemented. This 1,500-foot levee closure with four 10-foot concrete outlet culverts with lift gates was authorized for by the Flood control Act of 1954 (PL 780-83).

OBJECTIVE

The objective of this socioeconomic study is to analyze the area's past and present economic conditions and develop a baseline of future economic conditions for the area affected by the First Phase Project and the Birds Point-New Madrid Floodway levee closure (Levee Closure). A Limited Reevaluation Report (LRR) has previously been prepared which addresses the direct flood control effects of the First Phase Project. The LRR was a detailed affirmation of the economic effects of the First Phase Project and forms the basis of the values used in this EIS for this segment of the overall project. The LRR did not address the economic effects of the Levee Closure. For this reason, the economic effects of the Levee Closure segment of the overall project will be developed as part of this EIS.

The data provided in this section is used to describe and assess the area's economic and social well being. This section describes the existing economic and demographic parameters in the study area. The parameters described include: population, civilian labor force, employment, education, per capita income, agricultural characteristics, industrial activity, banking and savings,

and government finance. All data in this section are taken from the Bureau of the Census data and are converted to present (October 1996) price levels using BEA implicit price deflators.

The existing population, per capita income, and total employment parameters are projected to the year 2040 using Bureau of Economic Analysis (BEA) data. The BEA produces three sets of socioeconomic projection series for population, per capita income, and employment: State, BEA Area, and Standard Metropolitan Statistical Area (SMSA). BEA areas are amalgamations of counties that are selected for their interdependent economy. These BEA areas best represent the fertile river valley economy of the study area and were selected for this report as most representative. No methods are ideal for the projection of smaller areas, like that of the study area. Individual projections were made for each county and aggregated to form the study area total. Projections should not be interpreted as exact values, but only as indicators of the general direction and magnitude that growth may take in the 50-year period of analysis.

STUDY AREA

The study area for this socioeconomic base study consists of the 2 counties containing this project. These counties are: Mississippi and New Madrid Counties in Missouri. This area covers approximately 1,091 square miles. State and counties included in the study area along with the respective area in square miles are found in Table 31.

Table 31
1990 Total Land Area by County
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project

County	Square Miles
State Total	68,898
Mississippi	413
New Madrid	678
Study Area Total	1,091
Source: 1994 City and County Data Book	

PROJECT AREA

The project area includes portions of Mississippi and New Madrid Counties. It is divided into two distinct drainage basins: The St. Johns Bayou drainage basin and the Birds Point-New Madrid Floodway. Data presented in the LRR shows that the St. Johns Bayou area totals approximately 288,000 acres and is drained by St. Johns Bayou through the Mississippi River levee through a gravity outlet structure located near the City of New Madrid, Missouri. This structure provides the only outlet for the many natural and improved channels that form the basin's drainage system. The St. Johns Bayou area is primarily in agricultural use with approximately 261,000 acres of cleared land and 9,000 acres of scattered woodlands. The major crops grown in the area include soybeans, corn, cotton, wheat, and milo. Agriculture is the mainstay of the economy. It is supplemented by light industry in the surrounding urban areas. Railroad lines and several highways including I-55 provide access to the area. The community of East Prairie, to which this phase of the project is directed, had a 1990 population of 3,416.

The Birds Point-New Madrid Floodway (Floodway) has a length of about 33 miles, a maximum width of about 10 miles and totals approximately 132,000 acres. The Floodway is composed of alluvial lands which were subject to Mississippi River overflows before the advent of levees and are still subject to frequent lesser floods by Mississippi River backwater. Land use in the Floodway is primarily agricultural with approximately 114,000 acres in crop and livestock production. There are approximately 10,000 acres of wooded lands and 8,000 acres of other (scrub-shrub marsh, open water, etc.). The largest wooded tracts are located in Big Oak Tree State Park (approximately 1,000 acres) and the Ten Mile Pond Area (approximately 1,200 acres). As in the St. Johns Bayou area, the primary crops are soybeans, corn, cotton, wheat, and milo. The predominate crop in the frequently flooded backwater area is soybeans. No urban centers are located in the Floodway, although scattered farmhouses and other farm structures can be found. Most of these improvements are located outside of the backwater area. The very small rural community of Pinhook is located on a higher area approximately midway in the Floodway. State Highways 8 and 77 and numerous local roads provide access to the Floodway and its residents.

EXISTING CONDITIONS

Highly productive agricultural lands, wildlife and fishery resources, forested areas, streams, and wetland areas are the most valuable physical resources in the study area. Throughout history, favorable agricultural characteristics have been significant factors in the development of land use patterns in the study area. The existing land use reflects the importance of agriculture to the economy of the region. The existing conditions for the economic base area are reflected in the following paragraphs. They provide a brief discussion of its natural, human, and economic resources.

HUMAN AND CULTURAL RESOURCES

Changes in the population, composition, and distribution of the population of an area are the result of changing economic opportunities and are reflected in migration to cities from rural areas such as the study area. Population is the base for the existing and future labor supply available to industry, and the quantity and quality of this human capital is in turn reflected in employment and income returns to the area residents. The age class distribution of the population not only reflects its availability as a labor resource but also its potential demand for public and private goods, facilities, and services.

POPULATION

The historic population by county from 1970 to 1990 is shown in Table 32. The population of the study area has declined from 40,067 in 1970 to 33,226 in 1990, a 17.07 percent decline. Both counties in the study area, have shown significant decreases during this period. Only Mississippi County experienced a slight increase during any decade shown. From 1980 to 1990, Mississippi County's population increased 1.91 percent. The largest decrease during any one-decade was also in Mississippi County when its population decreased by 27.51 percent from 1970 to 1980. This trend is typical of most rural agricultural based economies. Many of the study area's former residents have moved to more urbanized areas which offer better job opportunities. This trend is reflected in nearby Scott County that showed a population increase of 18.42 percent (33,250 to 29,376) over the 1970 to 1990 period. Scott County includes the City of Sikeston with a 1990 population of 17,641.

Table 32
Historical 1970-1990 Population by State Area
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	1970	1970-80 Growth (%)	1980	1980-90 Growth (%)	1990	1970-90 Growth (%)
Missouri	4,676,501	5.14	4,916,766	4.07	5,117,073	9.42
Mississippi	16,647	-27.51	12,068	1.91	12,298	-26.12
New Madrid	23,420	-2.03	22,945	-8.79	20,928	-10.64
Study Area	40,067	-12.61	35,013	-5.10	33,226	-17.07
Source: 1994 County and City Data Book and respective Census Data.						

URBAN POPULATION

The study area does not contain any major metropolitan areas. However, it does contain four communities with populations over 2,500. The 1990 population for these four communities is shown in Table 33. Approximately 45.9 percent of the area's population resides in these four communities. Both counties contain two communities with populations over 2,500. Mississippi County has the largest percent urban population with 69.1 percent of its population residing in Charleston and East Prairie. New Madrid County has only 32.3 percent of its population residing in the two communities of Portageville and New Madrid. The area's closest major population center is Sikeston, Missouri in nearby Scott County with a 1990 population of 17,641.

Table 33
1990 Urban Population by County
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
(Population Centers Greater than 2,500)

County	Population Center	Population
Mississippi	Charleston	5,085
	East Prairie	3,416
New Madrid	New Madrid	3,350
	Portageville	3,401
Source: 1994 County and City Data Book.		

DENSITY

The study area is largely rural as reflected by the small number of persons per square mile. The population densities for the study area are shown in Table 34. The density for Mississippi County is 34 persons per square mile while the density of New Madrid County is slightly smaller at 31 persons per square mile. This compares to 75 persons per square mile for the State of Missouri.

Table 34
1990 Population Density by County
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	Density per Square Mile
Missouri	75
Mississippi	34
New Madrid	31
Source: 1994 County and City Data Book	

POPULATION BY AGE DISTRIBUTION

Population by age distribution is displayed in Table 35 for the study area by county and for the State of Missouri. Both counties have a greater percentage of preschool and school age children and elderly than the State of Missouri. The working age population (ages 18- 64) ranges from 54.8 percent in Mississippi County to 55.7 percent in New Madrid County. This compares to 60.3 percent for the State of Missouri. Urban areas tend to have a higher percentage of working age adults (60 percent) than more rural areas (50 percent), reflecting the greater number of employment opportunities.

Table 35
Population By Age Group
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1990 Census

Area	Age Group									
	Under 5	5-17	18-20	20-24	25-34	35-44	45-54	55-64	65-74	Over 75
Area	Percent By Population									
Missouri	7.2	18.5	4.6	5.5	16.7	14.4	10.2	8.9	7.7	6.3
Mississippi	7.3	21.6	4.3	4.4	14.1	12.5	10.4	9.1	8.9	7.5
New Madrid	7.2	22.1	4.1	4.9	14.4	13.0	10.2	9.1	8.5	6.4
Source: 1994 County and City Data Book										

HOUSING

The change in the number of households over time is one indication of the social characteristics of a community. Household data for the study area for 1980 and 1990 are shown in Table 36. The 1970 data is not comparable to 1980 and 1990 data because of a definitional change in what constitutes a household. During the 1980-1990 decade, the number of households declined in the study area while the State of Missouri experienced an increase. Mississippi County declined almost 2 percent while New Madrid County declined more than 3 percent. The State grew by more than 9 percent.

Table 36
1990 Historical Housing Characteristics
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	Total Number of Households		Growth Trend (%)	Number of Persons Per Household		Growth Trend (%)
	1980	1990	1980-90	1980	1990	1980-90
MISSOURI	1,793,399	1,961,206	9.36	2.67	2.54	-4.86
Mississippi	5,511	5,411	-1.81	2.82	2.63	-6.73
New Madrid	7,965	7,715	-3.14	2.86	2.65	-7.34
Source: 1994 County and City Data Book and respective Census Data.						

PERSONS PER HOUSEHOLD

Following the national trend, the number of persons per household has decreased over the decade in both counties in the study area at a rate ranging from 6.73 percent to 7.34 percent. The State has also declined, but at a slower rate at 4.86 percent. The range of the number of persons per household unit is also shown in Table 36.

MEDIAN HOUSE VALUES AND MEDIAN RENT

The relative value of median values in Table 37 can be used as an indicator of an areas economic strength. Both counties in the study area had housing values significantly lower than the state average. Values ranged from \$40,200 in Mississippi County to \$40,800 in New Madrid County. The State Median value was \$74,400, more than 83 percent higher than the study area values. Median rent values mirrored house values. Median rents ranged from \$286 in Mississippi

County to \$331 in New Madrid County. Mean rent value for the State was \$458 per month, or about 6.2 percent of the mean house value.

Table 37
Median Housing and Rent Values
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Level

Study Area	Median House Values (Dollars)	Median Rent Values (Dollars)
MISSOURI	74,400	458
Mississippi	40,200	286
New Madrid	40,800	331
Source: 1994 County and City Data Book		

NUMBER OF VEHICLES PER HOUSEHOLD

Although, once an indicator of affluence and mobility, the number of vehicles per household is losing it's ability to distinguish significant economic conditions in areas. It does, however, serve as a base indicator for the amount of potentially damageable property in a flooded area. There is little variance in the number of study area vehicles per household, and the total number of vehicles per county is reflective of that county's population Table 38. There are 19,747 vehicles in the study area. The number of vehicles per household (1.5) is slightly lower than the State average of 1.7.

Table 38
1990 Number of Vehicles Available by County
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	Total Vehicle (No.)	Per Household (No.)
Missouri	3,356,639	1.7
Mississippi	7,992	1.5
New Madrid	11,755	1.5

ECONOMIC RESOURCES

Labor force, employment, income, agricultural activity, and industrial and business statistics indicate the economic health of a region. An analysis of trends of some of these indicators provides a snapshot of the region's performance over a specified period. Taken together, these parameters describe the economic system of the area.

LABOR FORCE AND EMPLOYMENT

The civilian labor force population includes the working age population over the age of 16. Total civilian labor force statistics and employment and unemployment data for the area are presented in Table 39.

Civilian Labor Force and Unemployment

Relevant comparisons can be made between the study area and the State of Missouri totals. From 1970 to 1990, Missouri had a 36.7 percent increase in its civilian labor force. Labor force increases in both Mississippi and New Madrid Counties lagged behind with increases of 15.0 percent and 22.8 percent, respectively. This reveals that the labor force or pool is lagging behind the State and significantly behind urbanized areas. In general, counties with cities of more than 10,000 persons outperform more rural counties. Changes in employment over the same time period mirror the changes in the civilian labor force, but at a lower rate of growth. In Mississippi County, employment increased 11.9 percent while it increased 15.7 percent in New Madrid County. This compares to the State increase of 25.3 percent. Like the labor force statistics, this reveals that employment is also lagging behind other more urbanized areas.

As could be expected from the above statistics, unemployment also ran significantly higher than the State and other more urbanized areas. Unemployment in the study area was determined by the percentage of the civilian labor force that was not employed. County unemployment rates ranged from 8.5 percent in Mississippi County to 10.8 percent in New Madrid County. Both counties exceeded the State average of 6.2 percent.

Employment by Industry

Employment by industry for 1990 (Table 40) indicates that manufacturing is the number one employer followed by wholesale and retail trade. The percentage of people employed in each of these two sectors ranges from 24.0 to 25.5 and 18.3 and 18.4 percent, respectively. Agriculture is the third largest employer, with employment rates ranging from a high of 11.6 percent in Mississippi County to 11.9 percent in New Madrid County.

Table 39
1990 Labor Force Statistics and Historical Trends
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	1970 Civilian Labor Force (No.)	1980 Civilian Labor Force (No.)	1990 Civilian Labor Force (No.)	1970-90 Growth Trend (%)	1970 Employment (No.)	1980 Employment (No.)	1990 Employment (No.)	1970-90 Growth Trend (%)	1990 Unemploymen t Rate (%)
Missouri	1,845,402	2,283,059	2,622,783	36.7	1,767,310	2,103,907	2,367,395	25.3	6.2
Mississippi	5,160	5,831	5,935	15.0	4,781	5,228	5,429	11.9	8.5
New Madrid	6,930	8,451	8,513	22.8	6,404	7,722	7,596	15.7	10.8
Source: 1994 City and County Data Book and respective Census Data									

Table 40
1990 Employment By Industrial Sector
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	1990 Total Employment	Percent Distribution by Industrial Sector ¹					
		Agriculture	Manufacturing	Wholesale & Retail Trade ²	FIRE ³	Health Services	Public Administration
Missouri	2,367,395	3.4	18.6	21.7	6.3	9.2	4.3
Mississippi	5,429	11.6	24.0	18.3	3.9	5.8	2.9
New Madrid	7,596	11.9	25.5	18.4	3.2	6.9	3.2
¹ Includes wholesale and retail trade. ² Based on distributions of those sectors reported by the U.S. Census Bureau. ³ Includes finance, insurance, and real estate. Source: 1994 County and City Data Book							

Overall industry employment figures indicate that the study area has a greater percentage of its population dependent on agriculture than the State of Missouri. The study area is less dependent than the State on employment in Public Administration, Health, and Finance, and Insurance and Real Estate. Agricultural flooding can, therefore, have a greater effect on employment in the study area than it would elsewhere.

EARNINGS AND INCOME

The economy of the study area can be quantified by earnings and income to industry and labor, respectively. The sum of wages and salary disbursements, other labor income such as commissions and tips, and proprietors income is classified as earnings. Income comprises earnings by industry, plus property income and government or business transfer payments. Total earnings by industry, expressed in current dollars, are displayed in Table 41. Industry earnings are similar to the industry employment numbers described in the preceding paragraphs. Mining, construction, and manufacturing are the prominent industries in the study area in terms of earnings. These industries contribute a significantly larger percentage of earnings than for the State of Missouri average. Government services are second followed closely by services and retail trade. The percentage of government services compares favorably to the State average. The finance, insurance, and real estate sector is the lowest earnings sector for both study area counties, indicating that it plays a very small role in the area's economy. The percentage contributed by services, finance, insurance, and real estate lag far behind the State average.

Table 41
1990 Earnings By Industry
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Study Area	1990 Earnings by Industry ¹ (Millions)	Personal Earnings in Percent of Total Earnings					
		Agriculture	Manufacturing	Retail Trade	Finance, Insurance, and Real Estate	Health Services	Other ²
Missouri	65,820.9						
Mississippi	96.5	15.9	14.4	10.0	2.6	12.4	30.0
New Madrid	220.9	16.4	40.6	7.0	1.6	7.4	17.5
¹ Values expressed in millions of current dollars for given year based on U.S. Census Bureau. ² Mining, construction, transportation, public utilities and other services industries. Source: 1994 County and City Data Book.							

Personal And Per Capita Income

Total personal income (PI) is the principal component of gross national product. Personal and per capita income statistics from the 1990 Census are shown in Table 42. Total personal income for the study area is \$692,000,000. Fifty-nine percent is generated in New Madrid County. This is up approximately 70 percent over 1979 levels. Per capita income is an excellent indicator of comparative relative income for an area. In order to make comparisons of "real" change between counties over time in the study area, per capita income from the respective census documents was converted to 1996 price levels using the implicit price deflators. Those adjusted figures are displayed in Table 42. Per capita income in the study area in 1989 was \$11,611 in Mississippi County and \$11,727 in New Madrid County. Both figures are approximately 70 percent of the State of Missouri average of \$16,860. This is reflective of the rural nature of both counties. Rural per capita incomes are historically lower than more urbanized areas. As a measure of relative well being, these numbers can be compared to the comparable housing statistics. Housing prices in the study area are approximately 54 percent of the State average that indicates that housing may be relatively more affordable in the study area than other areas.

Table 42
Historical Income Statistics
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Level

Area	Personal Income (Millions \$)		Per Capita Income (\$)		
	By Year		By Year		1979-89 Growth (%)
	1979	1989	1979	1989	
Missouri	78,175.2	146,873.1	12,530	16,860	34.56
Mississippi	172.8	286.0	8,774	11,611	32.34
New Madrid	234.5	406.0	8,005	11,727	46.50
Source: 1994 City and County Data Book.					

AGRICULTURAL ACTIVITIES

Summary statistics for general farm physical characteristics for the study area for 1979 and 1992 are presented in Table 43. Data prior to 1979 is not useful for evaluating economic trends because of the massive restructuring of farm financial markets that took place in the mid 1970's, which significantly changed the economic structure of agriculture.

Number of Farms

Farms in the study area followed the national trend of consolidation. From 1979 to 1992 total land in farms decreased by 2.1 percent in Mississippi County and 6.1 in New Madrid County. The number of farms also declined in both counties by 30.4 and 38.1 percent, respectively while the size of the remaining farms increased by 40.5 percent and 51.5 percent. Total land in farms in the study area is 634,000. The State of Missouri showed a somewhat lower decline in the number of farms; and a slightly higher decrease in the total acreage in farms. The average size of Missouri farms increased only 15.0 percent, significantly lower than the study area's growth rate.

Table 43
General Agricultural Characteristics
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	1979 Total Number of Farms (No.)	1992 Total Number of Farms (No.)	Growth Trend 1979- 1992 (%)	1979 Total Land In Farms (1,000 Acres)	1992 Total Land In Farms (1,000 Acres)	Growth Trend 1979- 1992 (%)	1979 Average Size of Farms (No. Acres)	1992 Average Size of Farms (No. Acres)	Growth Trend 1979- 1992 (%)
Missouri	121,955	98,082	-19.6	30,849	28,547	-7.5	253	291	15.0
Mississippi	421	293	-30.4	271	265	-2.1	644	905	40.5
New Madrid	714	442	-38.1	393	369	-6.1	551	835	51.5
Source: 1994 County and City Data Book.									

Value of Agricultural Products Sold

The value of agricultural products sold in 1978 and 1992, based on 1996 dollars, appears in Table 44. This measures the relative changes in "real" farm product over time. Given the volatility of agricultural prices and the limited reference points that census data provide, this may or may not be an accurate picture of agricultural changes over time. The value of farm products sold decreased by 21.9 percent in Mississippi County and 17.4 percent in New Madrid County. Both counties declined at a rate that was slower than the State of Missouri decline of 32.6 percent.

Table 44
Value of Agricultural Products Sold in Millions of Dollars
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Level

Area	1978 (Millions \$)	1992 (Millions \$)	Overall Constant \$ Growth Trend 1978-1992 (%)
Missouri	7,556.1	5092.2	-32.6
Mississippi	114.6	89.5	-21.9
New Madrid	137.1	113.3	-17.4
Source: 1994 County and City Data Book and 1990 Census Data.			

INDUSTRY AND BUSINESS

With the decline in agricultural activity in the study area, there has been a corresponding decrease in some other sectors of the economy as well. Table 45 shows the number of establishments for the study area and their corresponding financial indicators for 1977. Table 46 shows the same information for 1992. The respective changes over time are presented in Table 47. Dollar values are at 1996 price levels. Comparisons of data in this table, as in many of the data tables, can be deceptive. Changes in the single-county states appear more significant than they should.

Table 45
Business and Industrial Activity 1977
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Level

Area	Manufacturing		Wholesale Trade		Retail Trade		Selected Services	
	No. of Est. ¹	Value Added by Manufacturing (Millions \$)	No. of Est.	Sales (Millions \$)	No. of Est.	Sales Receipts (Millions \$)	No. of Est.	Sales Receipts (Millions \$)
Missouri	7,355	31,873.3	10,007	85,439.4	43,219	38,774.3	43,509	9,127.9
Mississippi	14	19.5	31	242.9	175	110.1	99	6.9
New Madrid	16	0.0	49	370.9	254	147.2	160	14.6
¹ Number of establishments. Source: County and City Data Book, 1977-1978 respective census.								

Table 46
Business and Industry Activity 1992
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Level

Area	Manufacturing		Wholesale Trade		Retail Trade		Selected Services	
	No. of Est. ¹	Value Added by Manufacturing (Millions \$)	No. of Est.	Sales (Millions\$)	No. of Est.	Sales Receipts (Millions \$)	No. of Est.	Sales Receipts (Millions \$)
Missouri	7,843	39,918.1	11,236	80,960.4	32,185	44,870.8	36,361	24,068.0
Mississippi	12	25.6	25	139.8	86	89.8	51	16.9
New Madrid	15	D	47	208.6	127	115.4	61	23.1
¹ Number of establishments. D = Represents non-disclosure data. Information was not reported to the Census. Source: County and City Data Book, 1991-1992 respective census.								

Table 47
Percent Changes in Business and Industry Activity 1977-1992
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	Manufacturing		Wholesale Trade		Retail Trade		Selected Services	
	No. of Est.*	Value Added by Manufacturing	No. of Est.	Sales	No. of Est.	Sales	No. of Est.	Sales Receipts
Missouri	6.6	25.2	12.3	-5.2	-25.5	15.7	-16.4	163.7
Mississippi	-14.3	31.2	-19.4	-42.4	-50.9	-18.4	-48.5	148.1
New Madrid	-6.3	D	-4.1	-43.8	-50.0	-21.6	-61.9	57.9
*See Table E-I-15 for 1977 data and Table E-I-16 for 1992 data in order to compute the change in business and industry activity. D = Represents non-disclosure data. Information was not reported to the Census. Source: 1994 County and City Data Book.								

Manufacturing

Total value added by manufacturing in Mississippi County grew from \$19.5 million in 1977 (Table 45) to \$25.6 million in 1992 (Table 46), for an increase of approximately 40.1 percent (Table 47). Manufacturing information for New Madrid County could not be listed separately due to disclosure problems due to the limited number of firms in the county. Total establishments declined slightly in both counties. This was contrary to the trend in the State of Missouri where both value added and the numbers of firms were increasing. However, it is consistent in that value added per firm increased based on constant 1996 price levels.

Wholesale Trade

Wholesale trade seems to be a declining industry in the study area. The number of establishments decreased by 19.4 percent in Mississippi County and 4.1 percent in New Madrid County. Sales declined dramatically with decreases of 42.4 percent and 43.8 percent, respectively. This is contrary to the State of Missouri trend. The State had a 12.3 percent increase in number of firms with a 5.2 percent reduction in sales.

Retail Trade

Statewide, retail sales were almost the direct opposite of wholesale trade. The total number of establishments decreased by 25.5 percent with sales increases of 15.7 percent. However, establishments in both of the study area counties experienced 50 percent decreases in their number and 20 percent decreases in sales volume. This is reflective of a trend toward fewer and larger firms providing the area's retail goods.

Selected Services

Sales receipts for selected services increased for the study area by dramatically despite a decline in the number of providers. Mississippi County had a drop in the number of firms of 48.5 percent but a sales increase of 148.1 percent. New Madrid County had a significantly greater drop in the number of firms (61.9 percent) and an increase in sales volume of 57.9 percent. This compares to the State decrease in number of firms of 16.4 percent with a corresponding increase in sales volume of 163.7 percent. This area of the study area economy more closely paralleled the State totals than any of the other three. This follows the national trend in expansion of the service sector.

FINANCIAL STATISTICS

Statistics for local government and financial institutions located in the study area are discussed in the following paragraphs. These statistics may be seen as indicators of the financial health of the communities.

Local Government Finance

The balance sheet for local governments, depending on mandated expenditures, can reflect the health of the local economy. Growing revenues generally mean a thriving economy while growing expenditures coupled with declining revenues can mean an economy in distress. Unlike many parts of the country, the growth in local government revenues in the study area has exceeded the growth in expenditures. Overall government expenditures are presented in Table 48. In 1977 both counties in the study area spent significantly more than their revenues. By 1992 this trend was reversed with both counties having revenues exceeding expenditures. Over this period Mississippi County's revenues grew 19.3 percent while its expenditures fell 3.7 percent. New Madrid County experienced similar trends with revenues increasing 14.4 percent and expenditures falling 18.3 percent. Unfortunately for the study area, this trend does not reflect a thriving local economy. Instead it signifies the fiscal accountability of local government officials as they balance their budgets to prevent continued deficit spending and its resulting problems. To put this trend in perspective, these figures can be compared to the State of Missouri figures that show increases in revenues and expenditures of 153.7 percent and 164.1 percent, respectively over this period.

Table 48
Local Government Finances
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Level

Area	Total General Revenue (Millions \$)				Direct General Expenditure (Millions\$)			
	By Year			1977-92 Growth (%)	By Year			1977-92 Growth (%)
	1977	1987	1992		1977	1987	1992	
Missouri	7,111.1	8,188.4	18,037.5	153.7	6,785.0	8,500.8	17,919.2	164.1
Mississippi	22.0	21.1	26.2	19.3	26.6	22.5	25.6	-3.7
New Madrid	26.1	50.3	29.8	14.4	39.9	47.9	31.8	-18.3
Source: Census of Government for respective years.								

Banks and Savings Institutions

Statistics for banks and savings institutions in the study area are presented in Tables 49 and 50 by county. Tables 49 and 50 indicate that there are 14 banks in the study area and 3 savings institutions. Total bank deposits in 1992 for the study area were \$400,700,000. Savings deposits in the same year were \$45,500,000.

Table 49
1992 Banking Statistics by County
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Levels

County	Number of Offices	Bank Deposits (Millions \$)
Mississippi	4	198.6
New Madrid	10	202.1
Total	14	400.7
¹ Covers all FDIC-insured commercial and savings banks. Source: 1994 County and City Data Book.		

Table 50
1992 Savings Institutions by County¹
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Price Levels

County	Number of Offices	Savings Deposits (Millions \$) ²
Mississippi	2	21.6
New Madrid	1	23.9
Total	3	45.5
¹ Covers all SAIF-insured, OTS-regulated savings institutions. Source: 1994 County and City Data Book and Census Data.		

Cities over 10,000

Cities with populations of greater than 10,000 people are considered as major population centers. Although not located within the study area, Sikeston, Missouri is the nearest population center with over 10,000 residents. Located in the southern portion of Scott County, near the intersection of interstates 55 and 57, the town of Sikeston has a population of 17,641. The town is approximately 150 miles south of St. Louis, Missouri and 150 Miles north of Memphis, Tennessee. The economy of Sikeston is balanced between food processing, manufacturing, industrial, retail and service enterprises. Major local employers include Cargill, Inc., Cummins Gateway, Choice Brands USA, Heartland Wood Products, and Pepsi Cola Bottling. The town is also home to the Sikeston Jaycee Bootheel Rodeo, the largest rodeo in Missouri held every year the second week of August. The per capita income for Sikeston is \$17,672.

EDUCATION

The study area total for school enrollment is 8,845 based on 1990 Census Data. Table 51 indicates that some 7,199 students are enrolled in either Elementary or High School Program. According to the 1990 Census Data 938 students were in college and 313 of the high school students were dropouts. Of the study area total slightly over 50 percent had graduated from high school or obtained a higher degree. Of these, approximately 7 percent within the study area had either obtained a Bachelor's Degree or Higher.

FUTURE WITHOUT-PROJECT CONDITIONS

This section discusses the expected future economic environment of the study area in the absence of a project. Projections for three major economic indicators are presented: population, employment, and per capita income.

METHODOLOGY

Projections were made for the study area based on the Bureau of Economic Analysis area projections for: Memphis, Tennessee (BEA AREA 55) and St. Louis (BEA AREA 107). State and SMSA projections were not representative of the economic influences affecting the study area (see paragraph 5). All dollar amounts in the table have been converted to 1996 prices with the implicit price deflators. Each county's population, employment, and per capita income were projected using the appropriate BEA area growth factor. Individual county projections are found in Table 52.

Table 51
Education
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area

Area	School Enrollment, 1990					Educational Attainment, 1990		
	Total	Elementary or High School		College	High School Drop-Outs 1990	Persons 25 Years and Over	High School Graduate or Higher (%)	B.S. Degree or Higher (%)
		Total	Percent Public					
Missouri	1,292,623	860,230	87.5	337,146	33,249	3,291,579	74	17.80
Mississippi	3,646	2,933	97.3	360	122	9,042	49	7.20
New Madrid	5,199	4,266	96.2	578	191	13,020	52	6.70
Source: 1994 City and County Data Book.								

Table 52
Population, Income and Employment
St. Johns Bayou and New Madrid Floodway, Missouri
First Phase Project Study Area
1996 Prices

Area	BEA Area	1990	2000	2010	2020	2030	2040
MISSOURI							
Population		5,117,073	5,434,000	5,647,000	5,860,000	5,917,500	5,975,000
Per Capita Income		16,860	23,916	26,203	27,847	30,171	32,493
Employment		2,367,395	3,252,000	3,367,200	3,285,100	3,215,900	3,146,700
Mississippi	107						
Population		12,298	12,863	13,357	13,838	13,965	14,093
Per Capita Income		11,611	13,532	14,410	15,302	16,559	17,818
Employment		5,429	5,928	6,135	5,984	5,859	5,734
New Madrid	55						
Population		20,928	22,008	22,892	23,793	24,064	24,336
Per Capita Income		11,727	13,433	14,726	15,703	17,060	18,417
Employment		7,596	8,334	8,618	8,410	8,244	8,078
Source: 1994 City and County Data Book.							

PROJECTION BY ECONOMIC PARAMETER

POPULATION

Population is projected to increase by 15.6 percent, for a study area population of 38,429 by the year 2040. New Madrid County is expected to continue to be the most populous of the two with a population of 24,336 versus 14,093 for Mississippi County. The State of Missouri is expected to have a corresponding increase of 16.8 percent during the projection period.

EMPLOYMENT

Total aggregate employment is not expected to grow in the study area as fast as population. This component of the economic sector is only projected to increase by 6.0 percent by 2040. Employment by the year 2040 is expected to be 5,734 in Mississippi County and 8,078 in New Madrid County.

PER CAPITA INCOME

Mississippi County per capita income is expected to increase from \$11,611 to \$17,818 a 53.5 percent increase by 2040. New Madrid County's per capita income is also expected to increase from \$11,727 to \$18,417 a 57.0 percent increase. This compares to an expected 92.7 percent increase for the State of Missouri from \$16,860 to \$32,493. This shows that per capita incomes are expected to continue to lag behind the cities and more urbanized areas.

FUTURE WITH-PROJECT CONDITIONS

This section discusses the expected future economic environment of the study area after construction of Alternative 3-1B. Project construction would cause a great infusion of money into the study area. These added funds would generate many new employment opportunities. Also, the project will substantially reduce the area's flood problems and increase the area's agricultural production. This new source of annual income will also contribute greatly to the area's economy. Project related effects on sales volume, employment, income, and government revenues are presented in the following.

PROJECT CONSTRUCTION

Construction of both the MRL and LRR features of Alternative 3-1B will cost approximately \$77,762,000 of which a large portion will be spent in and around the project study area. These effects will be spread over the project construction period and will be proportional to the amount of yearly expenditures and end after completion of the project. This expenditure will generate an additional or secondary increase in sales volume of approximately \$51,523,000 for a total increase of \$129,285,000. This increase in money spent in the area will cause the creation of 1,060 jobs, 638 of which are directly related to project construction and 422 of which are related to the secondary effects. Area income will also increase substantially with a direct income increase of \$6,399,000 and a secondary increase of \$4,252,000 for a total increase in income of \$10,651,000. The above effects on sales volume, employment, and income will cause increased government revenues of approximately \$1,177,000 and increased government expenditures of approximately \$907,000.

ANNUAL IMPACTS

The annual benefits will also contribute to the local area economy. All of these effects will be realized within the project study area. They will begin after completion of the project and will accrue as long as the project continues to function. The primary impact will be on sales volume that will be composed of primarily of increased agricultural production. It will also cause a corresponding secondary increase that will translate into the creation of new jobs. Annual area income and annual government revenues and expenditures will also increase.

Appendix B

ECONOMICS AND SOCIAL ANALYSIS

Part 2

Revised 2006 Cost Estimates

Corps of Engineers, Memphis District
Mitigation Scenario A
22-Nov-05

ITEM DESCRIPTION	ACRES	ST. JOHNS FEATURE	MRL CLOSURE FEATURE	PURPOSE TOTAL	COMMENT
FLOOD CONTROL FEATURES					
St. Johns Bayou Basin		\$ 30,638,000			
New Madrid Floodway		\$ 15,014,000	\$23,838,000		
NMF Fishery Easements			\$2,481,000		
Total Flood Control		\$ 45,652,000	\$26,319,000	\$71,971,000	
BASIC MITIGATION FEATURES					
SJBB Reforestation	1293	\$ 3,914,000			
NMF Reforestation*	4126		\$11,029,000		Includes \$3,900,000 for 1657 ac of NM
Total Reforestation		\$3,914,000	\$11,029,000	\$14,943,000	mitigation purchased Jul 04
SJBB Shorebird Areas	105	\$ 453,000			
NMF Shorebird Areas	660		\$2,909,000		
Total Shorebird Features		\$453,000	\$2,909,000	\$3,362,000	
SJBB Waterfowl Easements		\$2,835,000			
NMF Waterfowl Easements			\$2,628,000		
Total Waterfowl Features		\$2,835,000	\$2,628,000	\$5,463,000	
SJBB Modified Borrow Pits	387	\$ 593,000			
Total Modified Borrow Pits		\$ 593,000	\$0	\$593,000	
NMF Vegetated Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Basic Mitigation	6571	\$ 7,795,000	\$ 19,570,000	\$ 27,365,000	
BIG OAK TREE STATE PARK					
BOTSP Water Supply			\$2,838,000		Entry to west of park, Fish AAHU's TBD
Total BOTSP Water Supply			\$2,838,000	\$2,838,000	
ADDITIONAL MITIGATION FEATURES					
Batture Reforestation	200		\$505,000	\$505,000	
Riley Lake Restoration to 286	430		\$1,782,000	\$1,782,000	
NMF 283.4 Fish Pool Fee Purchase	2000		\$2,636,000	\$2,636,000	Ponding to 283.4 1 Apr thru 15 May
Total Additional Mitigation Features		\$0	\$4,923,000	\$4,923,000	
TOTAL	8384	\$ 53,447,000	\$ 53,650,000	\$ 107,097,000	

* Includes preservation of 901 ac of existing woodlands and 1800 ac in the vicinity of BOTSP. Fish AAHU's for 1800 ac TBD.
Total acres purchased in fee excludes permanent water bodies, including the SJBB modified borrow pits.

Corps of Engineers, Memphis District
Mitigation Scenario B
22-Nov-05

ITEM DESCRIPTION	ACRES	ST. JOHNS FEATURE	MRL CLOSURE FEATURE	PURPOSE TOTAL	COMMENT
FLOOD CONTROL FEATURES					
St. Johns Bayou Basin		\$ 30,638,000			
New Madrid Floodway		\$ 15,014,000	\$23,838,000		
NMF Fishery Easements			\$2,481,000		
Total Flood Control		\$ 45,652,000	\$26,319,000	\$71,971,000	
	-				
BASIC MITIGATION FEATURES					
SJBB Reforestation	1293	\$ 3,914,000			
NMF Reforestation*	4126		\$11,029,000		Includes \$3,900,000 for 1657 ac of NM
Total Reforestation		\$3,914,000	\$11,029,000	\$14,943,000	mitigation purchased Jul 04
SJBB Shorebird Areas	105	\$ 453,000			
NMF Shorebird Areas	660		\$2,909,000		
Total Shorebird Features		\$453,000	\$2,909,000	\$3,362,000	
SJBB Waterfowl Easements		\$2,835,000			
NMF Waterfowl Easements			\$2,628,000		
Total Waterfowl Features		\$2,835,000	\$2,628,000	\$5,463,000	
SJBB Modified Borrow Pits	387	\$ 593,000			
Total Modified Borrow Pits		\$ 593,000	\$0	\$593,000	
NMF Vegetated Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Basic Mitigation	6571	\$ 7,795,000	\$ 19,570,000	\$ 27,365,000	
BIG OAK TREE STATE PARK					
BOTSP Water Supply			\$2,838,000		Entry to west of park, Fish AAHU's TBD
Total BOTSP Water Supply			\$2,838,000	\$2,838,000	
ADDITIONAL MITIGATION FEATURES					
NMF 284.4 Fish Pool Fee Purchase	2850		\$4,189,000	\$4,189,000	Pond to 284.4 1-30 Apr; Pond to 283.4 1-15 May
Total Additional Mitigation Features		\$0	\$4,189,000	\$4,189,000	
TOTAL	9034	\$ 53,447,000	\$ 52,916,000	\$ 106,363,000	

* Includes preservation of 901 ac of existing woodlands and 1800 ac in the vicinity of BOTSP. Fish AAHU's on 1800 ac TBD.
Total acres purchased in fee excludes permanent water bodies, including the SJBB modified borrow pits.

Corps of Engineers, Memphis District
Mitigation Scenario C
22-Nov-05

ITEM DESCRIPTION	ACRES	ST. JOHNS FEATURE	MRL CLOSURE FEATURE	PURPOSE TOTAL	COMMENT
FLOOD CONTROL FEATURES					
St. Johns Bayou Basin		\$ 30,638,000			
New Madrid Floodway		\$ 15,014,000	\$23,838,000		
NMF Fishery Easements			\$2,481,000		Fish AAHU's reflected in impact reduction
Total Flood Control		\$ 45,652,000	\$26,319,000	\$71,971,000	
	-				
BASIC MITIGATION FEATURES					
SJBB Reforestation	1293	\$ 3,914,000			
NMF Reforestation*	4126		\$11,029,000		Includes \$3,900,000 for 1657 ac of NM
Total Reforestation		\$3,914,000	\$11,029,000	\$14,943,000	mitigation purchased Jul 04
SJBB Shorebird Areas	105	\$ 453,000			
NMF Shorebird Areas	660		\$2,909,000		
Total Shorebird Features		\$453,000	\$2,909,000	\$3,362,000	
SJBB Waterfowl Easements		\$2,835,000			
NMF Waterfowl Easements			\$2,628,000		
Total Waterfowl Features		\$2,835,000	\$2,628,000	\$5,463,000	
SJBB Modified Borrow Pits	387	\$ 593,000			
Total Modified Borrow Pits		\$ 593,000	\$0	\$593,000	
NMF Vegetated Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Basic Mitigation	6571	\$ 7,795,000	\$ 19,570,000	\$ 27,365,000	
BIG OAK TREE STATE PARK					
BOTSP Water Supply			\$2,838,000		Entry to west of park, Fish AAHU's TBD
Total BOTSP Water Supply			\$2,838,000	\$2,838,000	
ADDITIONAL MITIGATION FEATURES					
Batture Reforestation	1050		\$2,651,000	\$2,651,000	
Riley Lake Restoration to 288	700		\$2,784,000	\$2,784,000	
SJB 283 Fish Pool Fee Purchase	1154		\$2,260,000	\$2,260,000	Ponding to 283 1 Apr thru 15 May
Total Additional Mitigation Features		\$0	\$7,695,000	\$7,695,000	
TOTAL	8388	\$ 53,447,000	\$ 56,422,000	\$ 109,869,000	

* Includes preservation of 901 ac of existing woodlands and 1800 ac in the vicinity of BOTSP. Fish AAHU's on 1800 ac TBD.
Total acres purchased in fee excludes permanent water bodies, including the SJBB modified borrow pits.

Corps of Engineers, Memphis District
Mitigation Scenario D
22-Nov-05

ITEM DESCRIPTION	ACRES	ST. JOHNS FEATURE	MRL CLOSURE FEATURE	PURPOSE TOTAL	COMMENT
FLOOD CONTROL FEATURES					
St. Johns Bayou Basin		\$ 30,638,000			
New Madrid Floodway		\$ 15,014,000	\$23,838,000		
NMF Fishery Easements			\$2,481,000		Fish AAHU's reflected in impact reduction
Total Flood Control		\$ 45,652,000	\$26,319,000	\$71,971,000	
	-				
BASIC MITIGATION FEATURES					
SJBB Reforestation	1293	\$ 3,914,000			
NMF Reforestation*	4126		\$11,029,000		Includes \$3,900,000 for 1657 ac of NM
Total Reforestation		\$3,914,000	\$11,029,000	\$14,943,000	mitigation purchased Jul 04
SJBB Shorebird Areas	105	\$ 453,000			
NMF Shorebird Areas	660		\$2,909,000		
Total Shorebird Features		\$453,000	\$2,909,000	\$3,362,000	
SJBB Waterfowl Easements		\$2,835,000			
NMF Waterfowl Easements			\$2,628,000		
Total Waterfowl Features		\$2,835,000	\$2,628,000	\$5,463,000	
SJBB Modified Borrow Pits	387	\$ 593,000			
Total Modified Borrow Pits		\$ 593,000	\$0	\$593,000	
NMF Vegetated Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Buffer & Wildlife Corridor			\$3,004,000	\$3,004,000	
Total Basic Mitigation	6571	\$ 7,795,000	\$ 19,570,000	\$ 27,365,000	
BIG OAK TREE STATE PARK					
BOTSP Water Supply			\$2,838,000		Entry to west of park, Fish AAHU's TBD
Total BOTSP Water Supply			\$2,838,000	\$2,838,000	
ADDITIONAL MITIGATION FEATURES					
SJB 283 Fish Pool Fee Purchase	1154		\$2,260,000	\$2,260,000	Ponding to 283 from 1 Apr thru 15 May
NMF 282 Fish Pool Fee Purchase	1215		\$1,519,000	\$1,519,000	Ponding to 282 from 1 Apr thru 15 May
Total Additional Mitigation Features	2369	\$0	\$3,779,000	\$3,779,000	
TOTAL	8553	\$ 53,447,000	\$ 52,506,000	\$ 105,953,000	

* Includes preservation of 901 ac of existing woodlands and 1800 ac in the vicinity of BOTSP. Fish AAHU's on 1800 ac TBD.
Total acres purchased in fee excludes permanent water bodies, including the SJBB modified borrow pits.

Corps of Engineers, Memphis District
St. Johns Bayou Basin Alternative 3-1B
7-Sep-05

ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT	CONTING.	Oct. 2005 PRICE LEVEL TOTAL	COMMENT
01 LANDS AND DAMAGES (w/ contin.)					21.3%		
Item 1, Already Completed	0	AC				\$0	
Item 2, New Madrid Pumping Station		AC				\$187,200	Reflects sponsor appraisal on 3 tracts for closure
Item 3, St Johns Bayou, Mile 0-3*		AC				\$412,000	These Real estate Estimates are derived from
Item 4a, St. Johns Bayou Mile 3-4.5*		AC				\$161,000	LRR, Appendix D, and merely Adjusted to
Item 4b, BDNM Levee Ditch mile 0-8.1*		AC				\$524,000	October 2005 Levels with some Channel
Item 5, St. Johns Pumping Station*		AC				\$661,000	Adjustments due to 200 foot to 120 foot and
Item 6, St. James Mile 0-7*		AC				\$772,000	Deletion of upper St. James (See markup of
Total 01 Lands and Damages					Total Cost	\$2,717,000	individual items from Appendix D)
02 RELOCATIONS					25%		
Item 4, St. Johns Bayou Mile 3-4.5	1	LS	\$748,804	\$749,000	\$187,000	\$936,000	
Item 4, BPNM Levee Ditch Mile 0-8.1	1	LS	\$65,053	\$65,000	\$16,000	\$81,000	
Item 5, Highway WW	1	LS	\$144,221	\$144,000	\$36,000	\$180,000	
Item 6, St. James Ditch Mile 0-7	1	LS	\$2,476,925	\$2,477,000	\$619,000	\$3,096,000	
Total Relocation 02				\$3,435,000	\$858,000	\$4,293,000	
09 CHANNEL IMPROVEMENTS							
Item 1, BPNM Mile 8.1-12.4 Complete							
Item 3, Lower St. Johns Bayou Excavation	1	Contract	\$763,846	\$764,000	\$76,000	\$840,000	
Item 3, Lower St. Johns Other tasks	1	Contract	\$863,252	\$863,000	\$129,000	\$992,000	
Item 4a, Upper St. Johns, Excavation	1	Contract	\$178,412	\$178,000	\$18,000	\$196,000	
Item 4a, Upper St. Johns other tasks	1	Contract	\$230,046	\$230,000	\$35,000	\$265,000	
Item 4b, BPNM Mile 0-8.1, Excavation	1	Contract	\$540,626	\$541,000	\$54,000	\$595,000	
Item 4b, BPNM Mile 0-8.1, Other Tasks	1	Contract	\$297,840	\$298,000	\$45,000	\$343,000	
Item 6, St. James Ditch, Excavation	1	Contract	\$447,044	\$447,000	\$67,000	\$514,000	Based on 80% of LRR amount x 1.189 x 1.12
Item 6, St. James Ditch, Other Tasks	1	Contract	\$297,560	\$298,000	\$45,000	\$343,000	Based on 66% of LRR amount x 1.189 x 1.12
Total 09 Channel Items				\$3,321,000	\$424,000	\$3,745,000	
13 PUMPING PLANTS							
St. Johns Pumping Station 1000 CFS							
Pumps	1	EA	\$1,810,430	\$1,810,000	\$272,000	\$2,082,000	
General	1	EA	\$47,396	\$47,000	\$7,000	\$54,000	
Sitework	1	EA	\$6,732,453	\$6,732,000	\$1,010,000	\$7,742,000	
Concrete	1	EA	\$2,492,336	\$2,492,000	\$374,000	\$2,866,000	
Masonry, Metals, Woods, Plastics	1	EA	\$603,023	\$603,000	\$90,000	\$693,000	
Doors/Finishes/Windows/Glass	1	EA	\$85,944	\$86,000	\$13,000	\$99,000	
Thermal Protection	1	EA	\$55,594	\$56,000	\$8,000	\$64,000	
Furnishings	1	EA	\$1,460	\$1,000	\$0	\$1,000	
Mechanical	1	EA	\$2,290,127	\$2,290,000	\$344,000	\$2,634,000	
Electrical	1	EA	\$1,127,543	\$1,128,000	\$169,000	\$1,297,000	
Total 13-St. Johns Station				\$15,245,000	\$2,287,000	\$17,532,000	
30 PLANNING, E&D	1	LS	3.5%				
Phase 1 St. Johns PED				\$895,000		\$895,000	
31 CONSTRUCTION MANAGEMENT	1	LS	5.5%				02, 09, & 13 Accounts indexed from Oct 03 to Oct 05
Phase 1 St. Johns S&A				\$1,456,000		\$1,456,000	price levels using index in H 47 unless otherwise
							noted
TOTAL PROJECT COSTS (Oct 05)	1	LS				\$30,638,000	1.12

New Madrid Floodway Alternative 3-1B
22-Nov-05

ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT	CONTING.	TOTAL	PUMP STATION FEATURE	MRL CLOSURE FEATURE	COMMENT
01 LANDS AND DAMAGES (w/ contin.)									
Lands and Damages	15	AC	\$ 2,000	\$ 30,000	\$ 8,000	\$ 38,000		\$ 38,000	ROW for Levee Closure Construction
Lands and Damages	197	AC	\$ 2,000	\$ 394,000	\$ 99,000	\$ 493,000		\$ 493,000	ROW for Setback Levee Grade Raise (Basic borrow only)
Non-Federal Acquisition	6	TR	\$ 5,600	\$ 34,000	\$ 9,000	\$ 43,000		\$ 43,000	
Federal Acquisition	6	TR	\$ 2,400	\$ 14,000	\$ 4,000	\$ 18,000		\$ 18,000	
Total 01				\$ 472,000	\$ 120,000	\$ 592,000	\$ -	\$ 592,000	Decrease in mitigation shown on Pump Station as a negative cost
02 RELOCATIONS									
Roads & Bridges	1	LS	\$ -	\$ -	\$ -	\$ -	\$ -		
Utilities	1	LS	\$ -	\$ -	\$ -	\$ -	\$ -		
Total 02				\$ -	\$ -	\$ -	\$ -		
13 PUMPING PLANTS									
New Madrid Pumping Station 1500 CFS & Gravity Outlet	1	EA	\$ 25,194,080	\$ 25,194,080	\$ -	\$ 25,194,000	\$ 13,101,000	\$ 12,093,000	This row reflects the bid price for the NM PS & gravity outlet; sum of rows 20 & 24-27 is total bid price + 6% escalation.
Total 13				\$ 25,194,080	\$ -	\$ 25,194,000	\$ 13,101,000	\$ 12,093,000	
11 LEVEES and FLOODWALLS									
Clearing & Grubbing	9	AC	\$ 265	\$ 2,000	\$ 1,000	\$ 3,000		\$ 3,000	
Levee Embankment	356,240	ECY	\$ 3.71	\$ 1,322,000	\$ 331,000	\$ 1,653,000		\$ 1,653,000	Closure + Adjacent Frontline Levee Grade Raise.
Aggregate Surfacing	1,500	CCY	\$ 29	\$ 43,000	\$ 11,000	\$ 54,000		\$ 54,000	Levee gravel roads, 12' wide, 6" compacted.
Turfing	9	AC	\$ 1,272	\$ 11,000	\$ 3,000	\$ 14,000		\$ 14,000	Bermuda grass.
Setback Levee									\$1,724,000
Clearing & Grubbing	387	AC	\$ 280	\$ 108,000	\$ 27,000	\$ 135,000		\$ 135,000	Borrow + Levee ROW
Levee Embankment, Grade Raise	2,054,524	ECY	\$ 2.80	\$ 5,753,000	\$ 1,438,000	\$ 7,191,000		\$ 7,191,000	Borrow pits within 1 mile.
Turfing	200	AC	\$ 1,344	\$ 269,000	\$ 67,000	\$ 336,000		\$ 336,000	Bermuda grass.
Total 11				\$ 7,508,000	\$ 1,878,000	\$ 9,386,000	\$ -	\$ 9,386,000	
30 PLANNING, E&D	1	LS	3.5%	\$ 1,145,000	\$ 286,000	\$ 1,431,000	\$ 744,000	\$ 687,000	E&D accounts for work already done on New Madrid Pump Station.
Total 30				\$ 1,145,000	\$ 286,000	\$ 1,431,000	\$ 744,000	\$ 687,000	
31 CONSTRUCTION MANAGEMENT	1	LS	5.5%	\$ 1,799,000	\$ 450,000	\$ 2,249,000	\$ 1,169,000	\$ 1,080,000	
Total 31				\$ 1,799,000	\$ 450,000	\$ 2,249,000	\$ 1,169,000	\$ 1,080,000	02, 09, & 13 Accounts indexed from Oct 03 to Oct 05 price levels using index in J 45 unless otherwise
TOTAL PROJECT COSTS (Oct 05)				\$ 36,118,080	\$ 2,734,000	\$ 38,852,000	\$ 15,014,000	\$ 23,838,000	1.12

Attachment 5
Biography of Donald C. Sweeney II, Ph.D.

Donald C. Sweeney II, Ph.D.

Donald C. Sweeney II is a Teaching Professor of Logistics and Operations Management, an Affiliate Professor of Economics and the Associate Director of the Center for Transportation Studies at the University of Missouri-St. Louis. Dr. Sweeney holds a Bachelor of Science degree in Mathematics and Economics from Knox College, Galesburg IL and a Ph.D. degree in Economics from Washington University, St. Louis MO.

Prior to joining the University of Missouri-St. Louis in January 2005, Dr. Sweeney was employed by the United States Army Corps of Engineers for 27 years as a regional economist, supervisory regional economist and senior regional economist. While with the Corps he served as the principal investigating economist or supervisory economist for a wide range of federal water resource studies including urban inundation reduction, rural inundation reduction, environmental restoration, hydropower, shallow draft navigation, deep draft navigation, recreation, and multi-purpose reconnaissance, feasibility and environmental impact studies. He chaired federal multi-agency task forces on the economics of water resource policy issues. In 2002, Dr. Sweeney was honored for his distinguished federal civil service career by being named the first recipient of the Environment, Science, and Technology, Service to America Medal awarded by the Partnership for Public Service.

Dr. Sweeney's current duties at the University of Missouri-St. Louis include teaching classes in economics, logistics and operations management. His current research interests are the economics of transportation systems, the modeling of logistics and supply chain networks and the development and use of decision support tools in managing logistics and supply chain networks. As Associate Director of the Center for Transportation Studies, Dr. Sweeney has served a wide range of research partners including: Covidien; the Federal Mogul Corporation; Israel Chemicals Limited; the Land-Air Corporation; the Missouri Department of Transportation; the Missouri Transportation Institute; Sigma-Aldrich Chemicals LLC; and the U.S. Army Corps of Engineers.

Attachment B
Comments of the Conservation Organizations

On the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)

REPORT OF DR. JOY ZEDLER ON
DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE
ST. JOHNS BAYOU/NEW MADRID FLOODWAY PROJECT (2013)
Dr. Joy Zedler (November, 2013)
(jbzedler@facstaff.wisconsin.edu)

I am Professor of Botany and Aldo Leopold Chair of Restoration Ecology at the University of Wisconsin-Madison. I have studied wetland and other aquatic ecosystems for over 45 years, and have more than 250 peer-reviewed publications. I have served on 4 panels of the National Research Council of the National Academy of Sciences, including a role as chair of the 2001 panel requested by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency to review the science and practice of wetland mitigation and to make recommendations for future practices. It issued a report called *Compensating for Wetland Losses Under the Clean Water Act*. This report was broadly embraced by the U.S. Army Corps of Engineers, which issued a memorandum to the field in 2003 highlighting key recommendations, reaffirming them, and calling the recommendations of this report either a “basic requirement for mitigation success” or a “guide for mitigation site selection.” U.S. Army Corps of Engineers, Memorandum to the Field on Adaptation of NAS Guidelines (Oct. 29, 2003). My comments on the 2013 Draft Environmental Impact Statement for this project draw heavily from this work and build on early comments I have made about this project based on extensive review of this and earlier versions of the environmental impact statement.

In my comments in 2006, I concluded: “[T]he claim that this mitigation fully offsets project impacts on aquatic resources is completely inconsistent with scientific understanding of wetland functioning, wetland replacement, wetland restoration, and mitigation of other aquatic areas, as well as inconsistent with established practice under the Section 404 program.⁴ The claim is so outside the range of reasonable scientific understanding that it cannot be seriously advanced as science-based. It therefore should be disregarded.” The final version of that Environmental Impact Statement was rejected by the federal District Court in the United States as arbitrary and capricious.

My judgment about the previous EIS also applies to the new one based on my review of large portions of the new draft EIS, including its key analyses of project impacts and mitigation. A striking feature of the new mitigation proposal is that the use of an updated and longer period of hydrologic record indicates that the project area is yet more frequently flooded than previously identified, with a large expansion of the two-year floodplain for example, and yet the proposed mitigation has roughly stayed the same or even declined from the previous mitigation found to

be inadequate. The main change is that the Corps is now relying on forms of mitigation that the Corps itself previously did not claim would provide the benefits now claimed. These include the following:

- A new and unsupported claim that work on Big Oak Tree State will provide vast fish habitat even though it is clear that river fish will have little or no access to the Park during their spawning and rearing periods;
- The claim that a few hundred acres of floodplain ponds will compensate for vast losses of inundation on thousands of acres of forested and farmed wetlands based on a changed system for scoring floodplain ponds and the unexplained rejection of previous agreements with the US Fish & Wildlife Service that borrow pits and other permanent water bodies should only be used to compensate for loss of other floodplain pond habitat;
- Reliance for mitigation on thousands of acres of reforestation of batture lands, which are different from the project area while previous versions of the EIS proposed little reliance on batture lands because of this inappropriate hydrology;
- Claiming wetland mitigation credit for the Ten Mile Pond waterfowl management area, a site which has long existed and was created by state agencies and which the Corps never claimed mitigation credit for before in the several previous draft and final environmental impact statements;
- Abandonment of plans to create a multi-hundred acre shorebird management area (itself inadequate) based in large part on the theory that Ten Mile Pond will mitigate most of the habitat and in part apparently on the theory that shorebird mitigation is not necessary.

I divide these comments into the following sections: (1) summary of the core effect of the project and (2) proposed impacts on wetlands; (3) the inconsistency between proposed mitigation plans (and the analysis of those plans) and the now scientifically accepted core principles of mitigation for wetlands and other aquatic ecosystems; (4) flaws with the reliance on HEP models; (5) how the shorebird mitigation analysis highlights those flaws; and (6) how the lack of a detailed mitigation plan is also inconsistent with wetland mitigation practice and the requirements for scientific evaluation.

1. Core Effect of Project and Mitigation

The core ecological importance of the project area is based on three key but

simple points. First, the Mississippi River ecosystem depends on regular and variable overflow of the river channel into an extensive and diverse floodplain, which provides direct habitat for the majority of river fish and the vast majority of waterfowl, shorebirds and other animal life and indirectly supports the river food chain. Second, more than 90% of this connected floodplain has been eliminated, which not only makes all floodplain rare but also makes calm, connected backwater capable of maintaining shallow-water areas over diverse flood conditions even more rare. Third, the project area is one of the largest remaining such habitats along the Mississippi River. According to Corps analyses, the two-year floodplain in the New Madrid and St. Johns Bayou basin now extends to roughly 45,000 acres, the five-year floodplain to 76,000 acres, and the area inundated by the river at some time more than 100,000 acres. .

At various places, the DEIS attempts to disparage the ecological value of the project site on the grounds that it is altered both hydrologically, through alteration of the Mississippi River's basic flows, and vegetatively, through clearing of most of the land for agriculture. It is true that these alterations somewhat alter and somewhat reduce the ecological functions. But virtually all aquatic ecosystems in the United States are heavily altered. The project area is as close to providing the functions of natural floodplains as can exist almost anywhere on the lower Mississippi River. It would be more accurate to say that in such a changed system, the persistence of the critical elements of floodplain functions by the project makes this site more important, not less.

2. Wetland Impacts

Of the tens of thousands of acres of regularly inundated floodplain, many are wetlands. The Corps of Engineers itself has acknowledged 14,040 acres of vegetated wetlands within the five-year floodplain. Virtually all of these acres will have their inundation areas and periods heavily diminished. That is in part because they are above the water levels at which gates will be closed at different times of the year, and in part because pumping and blockage of water will reduce the quantity of water that will remain in the floodplain after initial flooding. This assessment of 14,040 acres corresponds roughly with EPA's assessment of 14,614 acres of naturally vegetated wetlands within the five-year zone.

EPA, however, also identified acres within the basins above the 5-year flood zone. The DEIS indicates the Corps' intent to ignore impacts on these wetlands on the theory that they are little influenced by backwater flooding. It is true that the flooding from the river will not be the principal source of water for these wetlands, but further reduction in flooding is likely to alter these wetlands as well. These impacts therefore should be counted.

The even larger concern is “farmed wetlands.” The DEIS announces that it will consider only 1,096 acres of farmed wetlands based on estimates provided by NRCS. However, there is no analytical basis offered to justify these delineations. This estimate of farmed wetlands conflicts with analysis by EPA as part of an interagency team. The EPA analysis is expressed in EPA document titled: St. Johns Bayou/New Madrid Floodway Wetland Assessment Probability Survey Design, and an October 21, 2011 St. Johns Bayou and New Madrid Floodway (SJ/NMF) Wetland Assessment, both of which were obtained from the EPA. This analysis found 42,985 acres of farmed wetlands within the five-year flood zone of both basins (Probability Survey Design p. 4).

The two EPA documents provide extensive explanation of the methodologies employed, which included bench surveys using aerial photographs and field analyses. These methodologies were proper. Farmed wetlands are areas that were naturally vegetated wetlands as evidenced by their wetland (“hydric”) soils, which have been cleared for farming but are still flooded enough to meet hydrology criteria. The principal challenge in identifying these wetlands is determining their flood regimes. Water can come to these areas from precipitation, from local runoff and, in the case of the project area, from backwater flooding. Because there are no direct multi-year measurements that capture all these sources of water, the federal agencies that share responsibilities for wetlands have developed so-called “mapping conventions” that indicate the presence of extended flooding from various visual signatures in aerial photographs. They have also identified direct “secondary” hydrologic indicators that can be used at the field level. The EPA documents indicated that both tools were employed, including field visits by personnel from multiple agencies. The field visits also verified the presence of hydric soils. There is no reason to doubt the EPA assessment.

Even more definitively, the Corps’ own hydrologic data substantiate that there are roughly 9,200 acres of farmed wetlands created by backwater flooding. I illustrate how:

- The DEIS states the accepted view that the vast majority of the project area has hydric soils (and the existing of such soils has not been in dispute for the inundated parts of the project).
- The DEIS states at several points that a farmed wetland is any farmed area that has hydric soils and is flooded for 15 consecutive days during the growing season at least once every other year. In Table 3 and 7 of the Hydraulics Appendix at C-8, the Corps also states that the growing season used to delineate wetlands for the project is March 20th to November 11. The same tables also provide the flood line, not for 15-day inundation but for 14-day

inundation in each basin in Tables 3 and 7 of the DEIS. Those flood lines are 287.1 in St. Johns and 287.7 in New Madrid. Using Tables 3.1 and 3.2 of the DEIS, these elevations can then be applied to determine the quantity of agricultural land that is flooded for 14 consecutive days in both basins, and they come to 9,207 acres. (Tables 3.1 and 3.2 provide data only for foot level elevations, not tenths of a foot. But the DEIS indicates that the Corps interpolated linearly to derive areas inundated at tenths of a foot from these data and these calculations do the same). Tables 3 and 7 also show the 14-day inundation line after the project is built, and from that it can be found that 8,280 acres of these wetlands will no longer meet wetland criteria under the proposed project.

These data that find 9,207 acres of farmed wetland are for 14 consecutive days. They are a reasonable proxy for 15-day inundation. However, calculations of the 15-consecutive-day line were undertaken by Dr. Amy Lerner, a geographer at Princeton University, using a common statistical program and based on an excel spreadsheet of the Corps' sump elevation data presented in the hydraulics appendix and provided by the Corps to the Fish & Wildlife Service. This analysis shows that the 15-day flood elevation line is virtually identical at 287.7 in the New Madrid Floodway and 287 in the St. Johns Bayou Basin. Using these flood elevations with the data provided in Tables 3.1 and 3.2 of the DEIS shows that 9,174 acres of agricultural land meet the inundation for farmed wetlands. Based on the stipulations in the DEIS that the vast majority of the project area has hydric soils, and the field analyses described in the EPA wetland documents that found hydric soils, I therefore conclude that at a minimum 9,174 acres meet the legal criteria for farmed wetland.

To emphasize, these data are the Corps' own analysis of which acres in the project area flood from Mississippi River backwater, on what dates and for how long. The same hydrologic analysis underlies virtually every aspect of the EIS, from analysis of flood damages to analyses of the various habitat impacts. It is inconsistent and unjustified for the Corps to rely on this hydrologic analysis for all other analyses of the project and to ignore their implications for wetlands. I also emphasize that this analysis does not undercut the EPA analysis, which is based on approved interagency methodologies for examining the presence of water from additional sources beyond backwater flooding

The Corps has disputed that the elimination of backwater flooding on vegetated wetlands will eliminate their wetland status, but the Corps' own hydrologic analysis shows that the project will eliminate 8,280 acres of farmed wetlands. That is significant. Generally accepted wetland mitigation policy applied by

the Corps and the EPA to private parties under Section 404 calls for no net loss of wetland acres as well as functions. That is also the accepted scientific recommendation, dating to the Conservation Foundation's 1988 call for no net loss of acreage and function. However, none of the proposed mitigation will restore or create wetlands where they do not now exist.

This level of wetland impacts is large compared to other permitted projects. I am not aware of any permit issued under the Clean Water Act allowing the elimination of over 8,000 acres of wetland, and based on my experience of observing the federal wetland program, that level of impacts would not be permitted primarily for the economic benefits of agricultural drainage.

3. Functions of Farmed Wetlands and Inundated Agricultural Lands

The DEIS also states that it can ignore farmed wetlands (apart from those found by NRCS) because they do not provide wetland functions. The DEIS contains the following extraordinary statements: "An overwhelming amount of scientific literature concludes that while vegetated wetlands provide numerous ecological beneficial goods and services, wet agricultural areas provide a disservice and are largely anathema to conservation." DEIS p. 75. It supports this statement with 13 references, one of which is to a paper of mine. It also states on p. 76: "Farmland, whether considered farmed wetlands or prior converted cropland, in the project area provides an ecological disservice to nutrient removal." It further states: "Prior converted cropland was not considered wetlands because these areas have been so degraded that they no longer provide any significant wetland function." There are several basic flaws with this argument.

First, the DEIS admits that both farmed wetlands and even areas that might qualify as prior converted cropland in the project area provide important functions as habitat for fish, and water-dependent wildlife. These are wetland functions as specifically defined by the section 404(b)(1) guidelines. C.F.R 230.30 – 230.32

Second, the literature cited does not support the claims. For example, the paper of mine in *Frontiers in Ecology and Environment* 1:65-72 (2003) is about the ecological damage caused by the impacts of wetland loss, primarily drainage, to agriculture. It is about the impact of activities such as this project. It does not address the intermediate values of agricultural areas that remain inundated for extensive periods. To the extent I can tell, neither do the other articles cited.

Third and most fundamentally, the Corps is confusing the impact of fully drained wetlands for agriculture and the impact of the remaining inundation. Agricultural lands, of course, use fertilizer and are sources of nitrogen pollution to

the Gulf of Mexico. The primary sources of that pollution are fully drained agricultural lands in the drainage, particularly those areas with extensive tile drainage. The question is, what is the impact of longer inundation on those lands that remain inundated for many days? That includes those areas inundated long enough to be considered farmed wetlands and those inundated not quite long enough but still extensively.

The short answer is that the flooding in these areas will provide extensive water quality treatment. Wetlands “denitrify” nitrate, the form that runs off farm fields, through microbial activities that are present in saturated soils. Even two or three days of saturated soil conditions are enough to cause soils to become anaerobic and to start to denitrify. Large wetland areas are particularly effective because of the combination of conditions that will allow both nitrification and denitrification. The project area farmed wetlands and flooded agricultural fields tend to be flooded for many days, long enough to create these conditions. They therefore serve as a filter for pollutants running off agricultural fields higher up in the landscape, for pollutants in the soils of the agricultural lands themselves, and for pollutants in Mississippi River waters that back up into the floodplain.

Because of these values, restoration of wetlands, even farmed wetlands, has been identified as an important strategy for addressing the problems of the so-called “dead zone” in the Gulf of Mexico due to nitrogen runoff in the Mississippi River watershed.

Dr. Christopher Woltemade has provided previous reports and testimony about the large water quality benefits that can be estimated from the project area cite. Nothing in the materials cited would undercut that analysis.

4. Fundamental Scientific Flaws with the Proposed Mitigation

A striking feature of the mitigation proposed for the project is that it does not involve restoring wetland or floodplain hydrology to any areas that are not already frequently flooded. I attach on the next page a table of the principal mitigation proposed for the project in the fisheries appendix, and it shows how much of the mitigation proposed is based on artificial hydrologic manipulation of existing wetland areas. They include Big Oak Tree State Park and Riley Lake, both of which will have levees built around them to artificially manage water levels. The mitigation plans for waterfowl and shorebirds also rely heavily on artificial hydrologic manipulation of relatively small impoundments that will be surrounded by levees and manipulated through pumps. That includes Ten Mile Pond. The waterfowl mitigation also includes a proposal to close the gates and maintain waters permanently or semi-permanently inundated in the lower parts of the basins in

December or January for waterfowl.

Apart from hydrologic manipulation, the mitigation is to be supplied by altering the vegetation of existing flooded lands. They include bottomland hardwood (BLH) reforestation on lands that already flood (and in fact many of which will flood less frequently as a result of the project). Weighted by mid-season fish mitigation, 58% of the mitigation is provided by roughly 3,200 acres of reforestation in lands that will be behind levees and additionally drained by the project, and the vast bulk of the remainder is provided by batture lands between the levees. These lands also already flood, and have dramatically different hydrology, temperatures, flood durations.

In effect, compared to the project areas impacted, including 75,000 acres in the five-year floodplain, the mitigation is modest in area (8,700 acres excluding Ten Mile Pond, which already exists), involves no re-inundation of areas to offset the areas no longer inundated, and focuses heavily on artificial hydrologic management and structures of these smaller areas.

Table 23. Fisheries compensatory mitigation benefits (AAHU) in the St. Johns Bayou Basin.

Mitigation	Acres	Early	Mid	Late
Impacts		-386.6	-441.3	-245.3
BLH Restoration < 285'	400	40.7	41.9	15.4
BLH Restoration < 5-year	1,816	124.2	127.9	50.1
Riparian Buffer Strips	47	5.9	5.6	1.8
Ecologically Designed Borrow Pits	387	268.4	268.4	268.4
Net Gain		52.6	2.5	90.4

Table 24. Fisheries compensatory mitigation benefits (AAHU) in the New Madrid Floodway.

Mitigation	Acres	Early	Mid	Late
Impacts		-1,729.5	-2,061.1	-1,165.8
Big Oak Tree State Park and Surrounding Area	2,800	914.0	889.5	577.3
BLH Restoration < 285'	387	61.7	70.5	0.0
BLH Restoration < 5-year	1,970	179.3	84.7	0.0
Batture Land Reforestation	3,050	692.4	692.4	310.2
Ecologically Designed Borrow Pits	60	41.6	41.6	41.6
Floodplain Lake	432	326.8	326.8	326.8
Net Gain		486.2	44.4	90.1

Borrowing from my 2006 report, I explain why this mitigation is inconsistent with science, including modern understanding of how aquatic ecosystems function and of the efficacious mitigation of impacts on wetlands and aquatic ecosystems..

a. Inconsistency with accepted understanding of the importance of natural hydrology

Aquatic and wetland ecologists agree that natural hydrologic patterns are critical to the ecological functions of rivers and wetlands. In a report on riparian areas that include floodplains, the National Research Council committee called hydrology the “master variable” in driving the ecology of riparian areas, whose key components include not just broad averages but magnitude of water, frequency, duration, timing and rate of change. National Research Council, *Riparian Areas, Functions and Strategy for Management* (2002).¹

The focus on preserving and/or restoring natural hydrologic patterns reflects humility about the limits of our understanding of the role played by each variable for different ecological functions and hard-taught lessons about how alterations of natural hydrology have often had strong effects that were not well understood. For example, disruption of natural flow patterns, and the timing and amount of wet and dry conditions, of Florida’s Everglades are believed to be the root cause of the great declines of its fish and wildlife, and the restoration of these natural patterns of flow was the principal goal of a more than \$8-billion restoration plan authorized by Congress.

As early as 1852, Charles Ellet wrote in *Overflows of the Delta*. (Prepared under instructions from the War Department, Washington) that the Mississippi River was overflowing because of agriculture and levees that prevented floodwaters from moving onto their former floodplains. p. 24. The disruption of natural hydrology caused by levees is believed to be the root cause of the disappearance of more than a million acres of wetlands in coastal Louisiana and a significant contributor to increased hurricane damages. The Corps has proposed an even more expensive plan to restore natural hydrology to reverse the losses of these wetlands. And while these are two of the most high-profile examples of unintended negative consequences of

¹ This report explicitly addresses wetland mitigation. However, the same scientific principles apply to any mitigation activity required to offset impacts on aquatic ecosystems, including floodplain habitat for fish whether or not they qualify as wetlands. The Clean Water Act Section 404(b)(1) guidelines require that impacts on fish habitat be offset in general, as well as impacts on wetlands

altering natural hydrological conditions, hundreds of papers on rivers and wetlands have demonstrated adverse ecological consequences from hydrologic alteration for countless other rivers and wetlands. Numerous other papers have demonstrated that efforts to restore wetland and river habitat without restoring natural hydrologic patterns nearly always fail to reproduce key aquatic functions.

For these reasons and more, the report of the National Research Council of the National Academy of Sciences, prepared by the committee that I chaired, strongly emphasized the importance of naturally variable hydrological conditions. One of the major guidelines it set forth for wetland mitigation was as follows: “Restore or develop naturally variable hydrological conditions. Promote naturally variable hydrology, with emphasis on enabling fluctuations in water flow and level, and duration, and frequency of change, representative of other comparable wetlands in the same landscape setting.” National Research Council, *Compensating for Wetland Losses Under the Clean Water Act* p. 125 (2001). The report also stated, “Hydrology is most often cited as the primary driving force influencing wetland development, structure, functioning, and persistence. Proper placement within the landscape of compensatory wetlands to establish hydrological equivalence is necessary for wetland sustainability.” Ibid p. 45. Elsewhere, the report stressed, “Hydrological variability should be incorporated into wetland mitigation design and evaluation. . . . Hydrological functionality should be based on comparisons to reference sites during the same time period.” Ibid p. 45. The reference to “reference sites” is to provide a mechanism for imitating natural hydrology.

The Corps officially embraced this recommendation in its 2003 Mitigation Memo. This memo states: “Natural hydrology is the most important factor in the development of successful mitigation. Wetlands and other waters are very dynamic, and dependent on natural seasonal and yearly variations that are unlikely to be sustainable in a controlled hydrologic environment.” This memo went on to refer to our recommendation to establish natural hydrology as a “basic requirement.”

The Corps’ claim for this project that the loss of a vast area of seasonally flooded aquatic habitat could be replaced by unnaturally extended flooding on a small area of already existing wetlands would be an extreme example of what the NRC report recommended *against*.

b. Improper reliance on engineered hydrology

Related to the biological importance of natural hydrology is the report’s strong recommendation against the reliance on engineering structures even to establish natural hydrology, let alone to distort it. Our report discussed problems with the use of engineering structures to establish hydrology, and stated “natural

hydrology should be allowed to become reestablished rather than finessed through active engineering devices to mimic a natural hydroperiod,” i.e., a naturally variable hydrology. The Corps has accepted this recommendation as well, and writes in its memo regarding adoption of NAS recommendations, “Artificial structures and mechanisms should be used only temporarily. Complex engineering and solely artificial mechanisms to maintain water flow normally will not be acceptable in a mitigation proposal.”

Because the Corps’ proposed mitigation relies on these kinds of artificial engineering structures, not just for fish but also for waterfowl and shorebirds, this proposed mitigation violates its own established principles.

c. Inconsistency with importance of spatial extent and landscape position

The importance of preserving or reestablishing natural hydrologic variability is closely related to the importance reflected in landscape position. The NRC report notes that “[l]andscapes have natural patterns that maximize the value and function of individual habitats.” The report also encourages the preservation of “large buffers and connectivity to other wetlands,” and generally recommends locating mitigation sites in comparable landscape positions and with comparable hydrology as the impact site. NRC Report p. 124. Noting that “slight differences in topography,” i.e., elevation, have major impacts on hydrology and associated plants and animals, the report also calls for providing “appropriately heterogeneous topography.” Ibid p. 127. The Corps has endorsed this recommendation as well in the 2003 Mitigation Memo. For example, it writes, “attempting to place mitigation in a dissimilar ecological complex than that of the impact water is expected to result in a wetland/water unlikely to replace the functions of the wetland/water that was lost.” Memo p. 6. It also emphasizes the need for varied topography Memo p. 8-9.

For this project, the Corps proposes to create small areas to be managed in uniform ways as replacement for lost functions on an extensive expanse of wetlands and floodplain habitats with varied topography, extensive contiguity and, for much of the land, open hydrologic connectivity. This proposal violates the NRC panel’s recommendations as well.

The rationale for the NRC panel’s recommendations applies fully to the proposed project. The project area, according to the 2002 EIS, supports a wide range of fish, bird and amphibian species. These diverse species will use different kinds of habitats affected heavily by variable flood regimes, are adapted to take advantage of natural flood variability, and will therefore benefit from different aspects of that natural hydrology. Artificial flooding, even if it were to benefit some species, will almost certainly disadvantage others. The levees and water control structures

designed to achieve ponding will obviously serve to obstruct fish passage. Extensive flooding over a large number of acres for many days, as occurs today, will also do more to trigger water quality filtration functions than somewhat longer flooding over a very small number of acres. Existing flooding will create a range of microhabitats, and interactions between floodplain and stream networks, that could not be mimicked by extended ponding on a small number of acres. The NRC has recommended the importance of these variations in microhabitat explicitly on floodplains:

"River-floodplain systems have a lateral structure that begins at the main channel and progresses through undefeated and vegetated channel borders and floodplain habitats (backwaters and seasonally flooded vegetation types). Backwaters and large-scale eddies provide refuges from the high velocities and colder winter temperatures of the main channel. Within each of the border and floodplain areas, there are distinct patches, usually determined by small differences in land elevation, that in turn determine the period of inundation (or water depth, in permanently flooded areas) and soil saturation."

National Research Council, *Restoration of Aquatic Ecosystems* p. 181 (citation omitted). The NRC emphasized the importance of this patchiness, writing that "restoration necessarily involves maintenance or recreation of the original patchiness." p. 183, and emphasizing that floodplain connectivity is critical because "[a]nother way in which the character of rivers is drastically altered is by cutting off interactions with the riparian zone and floodplains." Ibid p. 169.

There is also the real risk, and in this case a likelihood, of a range of additional unintended adverse environmental consequences, of which blockage to fish passage is only the most obvious. They include the following common adverse consequences for artificially-prolonged hydroperiods that may occur particularly in the proposed shorebird and waterfowl impoundments:

- Rapid invasion of ponded areas by invasive wetland weeds such as cattails (*Typha* spp.), which can, within a single growing season, form dense canopies that cover wet soils
- Exclusion of native fish and/or shorebird use of weed-dominated wetland impoundments even beyond the problems that artificial barriers pose to fish access
- Eutrophication and fish kills in persistent, warm water

Artificially prolonged flooding could also result in a range of biochemical impacts that are hard to anticipate. In the face of the limitations of our

understanding, and the repeated demonstration that alterations to natural hydrologic variability tend to have highly adverse consequences, the accepted understanding is that mitigation and other forms of environmental restoration should focus on reestablishing natural hydrologic variability. In this matter, the Corps has proposed to do the opposite of these recommendations.

The proposed project would dramatically reduce or eliminate flooding according to a relatively natural pattern on tens of thousands of acres of wetlands and other valuable floodplain areas, and replace them in part by artificially manipulating the hydrology on a small number of acres of already existing wetlands and in part by planting trees on already flooded land. According to established understanding, the focus of mitigation should be reestablishing of relatively natural flooding on appropriate presently dry areas, typically former wetlands, to offset the impacts on the proposed wetlands. Doing so requires mitigation sites roughly comparable in size to those affected (and often more).

Proper mitigation would probably undermine the economics of the project because it would essentially involve rewetting an area equivalent to that which this project will drain. But that is the point: Under the Clean Water Act program, wetland impacts are designed to be for unavoidable impacts to wetland systems necessitated by important economic activities that therefore warrant the effort to reproduce the lost wetland areas and functions elsewhere. The fact that this project can only be economically justified if it fails to follow these mitigation principles applicable across the regulatory program to private parties and local governments should not be a justification for violating these principles and cannot warrant a finding that project impacts are mitigated.

5. Inappropriate Use of Habitat Models

A related flaw with the Corps' analysis is its misuse of its habitat models, which go under the general category of Habitat Evaluation Procedures or HEP. By using these models to quantitatively estimate mitigation acreage requirements for very different kinds of habitat under very different hydrologic conditions, the Corps has used these models beyond any scientifically accepted level.

HEP models attempt to evaluate habitat for animals on the basis of very few criteria. For example, the fish model used by the Corps for this project is based entirely on numbers of average daily flooded acres and the different kinds of vegetation on those acres. In and of itself, it does not factor in such obviously critical factors as extent of contiguous habitat, hydrologic variability, microhabitats, temperature, water velocity, relationships among habitat types, and conditions under extreme flooding or drought.

The models also ignore the values of habitat diversity for the broad range of species being evaluated, providing one score for all fish, one score for all waterfowl and one score for all shorebirds. Because of their simplicity, HEP models have generally come into disrepute, particularly if used for more than one target game species. The HEP models for this report are intended to cover a range of species that in reality have different needs. Thus, when the National Research Council panel evaluated analytical tools for wetland mitigation, it noted that HEP models have often been used in the past, but did not recommend their continued use. *Compensating for Wetland Losses*, ch. 7. The National Research Council panel recommended the use of assessment techniques that meet eight conditions, few of which are met by HEP models.²

However, even if HEP models are to be used, it is broadly understood that they can only be used under conditions that essentially compare very similar habitats in all respects other than those varied by the model. For example, the fish HEP model can be used, if at all, to compare different floodplain habitat values for acres with different vegetation that experience similar patterns of natural hydrologic variability in similar landscape contexts. It cannot be used to compare habitats with very different kinds of hydrology, such as one relatively natural and the other highly managed and artificial. The most obvious reason is that no science went into the development of the model to reflect these important differences, such as those between relatively natural hydrology over an extensive landscape and those in a small area subject to artificial flooding and with barriers to fish access. When HEP models are used in fundamentally different hydrologic or landscape settings, or with very different ranges of other important characteristics, they are no longer science-based. To illustrate the problem, imagine an accurate model used to assess the number of annual calories needed by adults of different weights and heights. Such a model would not imply that adults would be equally healthy regardless of whether they received those calories through balanced meals or through candy bars. Neither would it imply that adults would be healthy whether they eat these calories in three meals a day or in one meal in a single day. At best, the Corps is attempting to use a habitat model for fish that was developed by comparing sites with comparable

² Key recommendations include that the assessment technique “includes reliable indicators of the important wetland processes (hydrology, sedimentation and primary production)”; that it “incorporates effects of position in landscape,” that it “assess all recognized functions”; that it is “sensitive to changes in performance over a dynamic range” (such as difference in conditions in both very large and very small floods). *Compensation for Wetland Losses* p. 136-137. None of these conditions are met by the HEP models used for this project.

hydrology and landscape to evaluate mitigation sites with completely different hydrology and landscape position.

6. Shorebird Example

The discussion of shorebirds and proposed “mitigation” illustrate the flaws with the project and the mitigation plans. A broad number of shorebird species, use the Project area for both spring and fall migration and are an important part of the Mississippi River ecosystem. These species vary in their precise needs, using areas of different water depths, consuming invertebrates such as insects and worms, and in some cases, catching small fish. Most are visual feeders that depend on open areas, which is why wet fields can attract shorebirds to forage. As water moves up and down natural floodplains, there is a constantly moving front of shallow water that makes available different areas for shorebirds, some longer legs and others with shorter legs, such that they collectively feed in a diversity of habitats, including agricultural lands and edges of marshes, as well as in the same habitat at different times, depending on water depth and other factors. The DEIS calculates that the project will eliminate 731 acres of “optimized habitat.” In light of different habitat value assigned to areas of different water depth, that implies that something on the order of 1,300 acres or more of the floodplain are flooded on average at all times throughout the entire Spring migratory period at depths that permit feeding by some species of shorebirds.³

The first presumption behind the mitigation is that this diversity of habitats and conditions can be replaced by managing and permanently inundating roughly 1,286 acres of agricultural lands every single year for 93 days in the Spring. This claim is simply not credible. There is no reason to believe that shorebird food supplies available every single day over 93 days of flooding on the same acres would be equal to that available on what now exists over thousands of acres flooded each to the right depth for shorebirds for only a portion of those days. This analysis also assumes that the only habitat values are food supplies and that shorebirds of multiple species will use one small confined area to the full degree that use much larger, diverse and variable areas. And it ignores the fact that dense bird usage makes birds susceptible to the transmission of disease.

This analysis also ignores the likelihood that wetland inundated with shallow water for 93 consecutive days will be invaded by marsh vegetation (most predictably

³ I deduce this from the fact that the Corps indicates that 1,286 acres of habitat flooded every day during the shorebird season would be needed as mitigation based on its likely variable depths, which implies that similar numbers of acres are already flooded on average assuming a similar distribution of depths.

cattails, which can invade and dominate ponded areas within 93 days) and that even if the mitigation site will support invertebrates, dense vegetation will not attract many shorebirds. Active management would be required at all times to prevent dense weed invasions.

Second, the mitigation project would result in a net loss of wetland area and habitat for shorebirds because the plan says that the existing waterfowl management area, Ten Mile Pond, will provide 993 (77%) of the 1286 wetland acres lost by constructing the New Madrid Floodway. That cannot comply with Clean Water Act requirements for the obvious reason that the Ten Mile Pond wetland already exists. There is also no demonstration that the Ten Mile Pond area is managed or could be managed to provide the proposed water depths across the entire size, even if they were usable by shorebirds. And the fact that the Ten Mile Pond area is also being flooded and used to provide waterfowl habitat in the winter (and therefore prior to the start of the shorebird season indicated as March 15th) means that its food supplies would already be partially depleted and management for waterfowl would compete with management for shorebirds.

Finally, the mitigation plan suggests that there is no real need to mitigate for shorebirds, arguing that shorebirds would not originally have used the project area because it would have been wooded, and on the premise that mitigation might otherwise involve converting forest to agricultural land. Both claims are misguided.

- Although shorebird use would probably have been limited in the project area when it was mostly forested, overall the lower Mississippi Valley provided extensive habitat through its network of mudflats, sandflats, shallow pools and marshes. (Some of the project site was undoubtedly also unwooded.) The cut-off and drainage of more than 90% of the floodplain has severely reduced that available habitat. Fortunately, some human modifications have simultaneously made new habitats available, and those species that could take advantage of them have continued to survive. People have altered the overwhelming majority of the remaining habitat in the United States. If alterations were a justification for ignoring conservation of altered habitats, the bulk of the remaining habitat in the United States would be quickly extinguished.
- The ignoring of project impacts on shorebird habitat is a kind of Catch-22. Under standard mitigation principles and practice, the reduction of tens of thousands of acres of relatively naturally (and therefore irregularly) flooded aquatic habitat would need to be compensated by re-flooding tens of thousands of acres elsewhere in

ways designed to mimic natural patterns as much as possible. Compensatory mitigation of this type is nearly always required of private parties, and it is inherent in the goals of maintaining spatial extent of aquatic ecosystems. In turn, the goal of spatial extent is based on the judgment that maintaining wetland area is necessary to preserve wetland functions, particularly in light of the importance of maintaining natural hydrology.

For this project, of course, re-flooding other farmland, marsh and woodlands to offset the drainage of the project area would presumably not allow the project to be cost-effective because it would cancel out the economic gains of draining farmland. But that does not change the scientific judgment of the type of mitigation truly necessary to offset the project, and it also explains why large agricultural drainage projects cannot comply with the requirements of the Clean Water Act.

Ruling out the proper mitigation, the DEIS then correctly notes that it would undermine other conservation values to convert flooded forest to flooded agricultural land. But the correct approach is to do mitigation properly by re-flooding comparable areas, which recreates the habitat needs not only of shorebirds but of the diversity of other species. The proper refusal to consider leveling existing forests provides no rationale for ignoring the basic rules of mitigation; nor does it diminish the lost habitat values to shorebirds.

Shorebirds are a major part of the Mississippi River valley ecosystem. They rely on vanishingly few remaining locations that flood in the extensive, diverse and variable ways of the project area. The loss of shorebird habitat under the project would be extensive, and the proposed mitigation is mostly non-existent.

7. Failure to Specify Particular Mitigation Sites or Other Attributes of Detailed Mitigation Plan

Virtual all assessments of wetland mitigation, as summarized in *Compensating for Wetland Losses Under the Clean Water Act*, have found that most wetland mitigation projects have shortcomings to differing degrees, in that the target wetland mitigation has not fully replaced the lost wetland area and functions. The reasons for their shortcomings include the fact that compensating for wetland losses is technically very challenging and subject to a range of difficulties for even the most promising projects. Another reason is that the degree of commitment to wetland mitigation sites tends to wane once the underlying project has gone forward. The degree and likelihood of a project achieving its stated objective

depends on the characteristics of the proposed mitigation sites.

One of the questions addressed by the National Research Council panel in *Compensating for Wetland Losses* was whether mitigation projects should therefore be completed prior to authorizing project impacts. The panel rejected this requirement on practical reasons, while noting that this level of certainty is one of the potential benefits of wetland mitigation banks. But the report emphasized the critical importance of providing a detailed mitigation plan before approval of project impacts. NRC Report p. 101.

Review of a specific mitigation site and reasonably detailed restoration plans are critical to any assessment of the likelihood and degree of mitigation, as well as the likelihood and degree of compliance. These are not minor details that can be resolved later. Given the challenges facing mitigation, there can be no legitimate determination that mitigation is likely to offset project impacts without this information. The NRC panel also recognized that mitigation ratios, i.e., the area of mitigation needed, need to be adjusted to reflect the prospects for achieving compliance. NRC Report p. 150. That too cannot occur properly without detailed advance information about mitigation sites and restoration plans. Such levels of details do not support any legitimate judgment about the extent to which mitigation will truly offset project impacts, and it is inconsistent with Corps-recommended practice as represented to the NRC panel

A few examples illustrate the significance.

- The DEIS claims that fish will be able to access Big Oak Tree State Park. The Park is above the elevation level at which inundation will normally be allowed to occur, and gates will have to be closed most of the time when floodwaters could reach the Park. It is also unclear how waters can reach the Park from the river during the bulk of the late winter, spring and summer when allowing water to move through a canal toward the Park would allow that water to spill over and flood adjacent lands that are supposed to be dry. The lack of detail of the mitigation plan is probably obscuring these large technical obstacles.
- Mitigation relies heavily on batture lands, which are in fact highly unlikely to provide the kind of calm, still waters with relatively higher temperatures necessary for spawning fish. Identification of specific mitigation sites would be necessary to examine if appropriate mitigation lands could truly be found.
- The mitigation plan claims that thousands of acres in the floodplain will be simultaneously acquired at high enough elevations to support

mast-producing trees for waterfowl but at low enough elevations to provide enough flooded habitat for fish as well as waterfowl. Identification of specific mitigation sites would permit closer examination of these claims.

Detailed mitigation plans are not merely necessary to make sure that proper mitigation is carried through, but they are also necessary to demonstrate that the proposed mitigation can truly achieve the claims of fully mitigation project impacts.

For all these reasons, I do not believe it is scientifically credible for the DEIS to claim that the impacts of the proposed project on aquatic resources would be fully or even substantially mitigated.

This document represents my views to the best of my knowledge, information and belief. I make these views subject to penalties for unsworn falsifications to authorities.



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Date: 25 November 2013

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PROFESSIONAL EXPERIENCE and EDUCATION

1998- Professor of Botany; Arboretum Research Director, Univ. of Wisconsin, Madison
1980-98 Professor of Biology, San Diego State University (SDSU)
1986- Director, Pacific Estuarine Research Laboratory, SDSU
1997 Associate Director, Environmental Science Program, SDSU
1991-3 Director, Coastal and Marine Institute, SDSU
1969-80 Asst. and Assoc. Professor, SDSU
1968-69 Instructor in Botany, Univ. of Missouri, Columbia
1968 Ph.D. in Botany (Plant Ecology), Univ. of Wisconsin, Madison
1966 M.S. in Botany, Univ. of Wisconsin, Madison
1964 B.S. in Biology, Augustana College, Sioux Falls, So. Dak.

RESEARCH INTERESTS

Wetland ecology; structure and functioning of wetlands; restoration ecology (especially adaptive restoration--learning while restoring through large field experiments); interactions of native and invasive species, diversity-function relationships in restoration sites; use of native species to manage stormwater; long-term monitoring; applying scientific information to ecosystem management.

PROFESSIONAL SOCIETIES AND EDITORIAL BOARDS

Society for Ecological Restoration International
 Editorial Board, *Restoration Ecology*, 2004-
Environmental Law Institute
 National Wetlands Newsletter Advisory Board 1998-
Society of Wetland Scientists
 International Conference Co-Chair, 2009
Ecological Society of America
 ESA Vegetation Section Chair, 1996-7
 ESA Editorial Board, *Ecological Applications*, 1992-4; reappointed 1999-2005
Estuarine Research Federation

ERF Vice President, 1987-89
ERF Program Chair, 10th Biennial International Conference, October 1989
ERF Editorial Board, *Estuaries*, 1984-89
American Ecological Engineering Society
Editorial Board, *Ecological Engineering: The Journal of Ecotechnology*, 1991-2005
Non-society journals:
Advisory Board, *National Wetlands Newsletter*, 1997-
Editorial Board, *Wetlands Ecology and Management*, 1988-2005
Editorial Board, *Ecosystems*, 1997-2000
Science Advisor, *Ecological Restoration*, 1988-2011

HONORS and AWARDS

Elected Fellow, Ecological Society of America, August 2013
Elected Fellow, Society of Wetland Scientists, May 2013
Stanford/Hopkins Marine Station: Scientific Working Group: thresholds/indicators in marine systems, 2013-
International Panel (8 mbrs) to advise South Korea's National Institute of Ecology, Oct. 2012-
Wisconsin Natural Areas Preservation Council, UW System Representative, 1999-2013
Wisconsin Chapter of The Nature Conservancy, Board of Trustees, 2004-
Environmental Defense Fund, Board of Trustees, 1998-2007; National Advisory Council, 2007-
Distinguished Seminar Speaker, Jones Ecological Reserve, Georgia, Feb. 2010
Paul Errington Distinguished Lecture, Iowa State U., March 2006.
Career Achievement Award, Augustana College: 2004
D. J. Dyksterhuis Distinguished Lecture, Texas A & M U., April 2003.
William A. Niering Outstanding Educator Award (first recipient): Estuarine Research Federation, International Biennial Conference, Tampa, Fla., November 2001
Southern California Wetlands Recovery Project: First Award for Achievements in Regional Wetland Conservation, October 2000
The Nature Conservancy National Governing Board, 1995-2004
Prepared the Society of Wetland Scientists' Position Paper on Defining "Wetland" 1999.
National Wetlands Award (Environmental Law Inst. & Environmental Protection Agency) for Science Research, demonstrating "an extraordinary commitment to the conservation and restoration of the nation's wetlands," May 1997
SDSU Biology Department Teacher-Scholar Award, May 1997
SDSU Alumni Association Award for Outstanding Faculty Contributions to the University, 1997
National Oceanic and Atmospheric Administration, Sanctuaries and Reserves Division, Special Award for outstanding contributions to the understanding of estuarine ecology and for contributions to the Tijuana River National Estuarine Research Reserve, March 1997
Society for Ecological Restoration, Theodore M. Sperry Award, 1995
National Research Council

Committee on the St. Lawrence Seaway: Options to Eliminate Introduction of Nonindigenous Species into the Great Lakes, Phase II. 2006-08.
Committee on Wetland Characterization, 1993-94
Water Science and Technology Board, 1991-94
Committee on Restoration of Aquatic Ecosystems, 1990-92
Planning Committee for the Second National Forum on Biodiversity, 1996-98
Committee on Wetland Mitigation (chair), 1999-2001
Chancellor's Distinguished Lecturer, University of California, Irvine, April 1992
Phi Beta Kappa Lecturer, SDSU, Fall 1992
Roger Revelle Perpetual Award, Oceans Foundation, 1991
Fellow, San Diego Natural History Museum, 1989
SDSU Meritorious Performance and Professional Promise Awards, 1985, 1988

ADVISORY PANELS/COMMITTEES

Lead Scientist advising the EPA Science Review Board to endorse the EPA Report on Wetland Connectivity. 2013.

Science Advisory Group, Nature Reserve of Orange County (NROC), California 2013

Advisory Panel, Stanford U./Hopkins Marine Station Analysis of Thresholds for Marine Ecosystem Disruption, 2013-

Advisory Panel, South Korea National Institute of Ecology, Seochon, 2013-

Science Review Panel for San Francisco Bay Responses to Climate Change Effects, 2012-

Science Advisory Council for Ormond Beach Restoration, The Nature Conservancy and CA State Coastal Conservancy, 2011-

Invasive *Spartina* Removal in San Francisco Bay, CA State Coastal Conservancy, 2011-

Science Advisory Council for Ballona Wetlands, Santa Monica Bay Restoration Commission, 2010-

International Crane Foundation Advisory Board, 2010-

National Ecological Observatory Network (NEON) Science Technology and Education Advisory Committee, 2008-2010

Wisconsin Department of Natural Resources, Natural Area Preservation Council, 1998-2013

State of Washington Salmon Restoration Validation Monitoring Panel, 2000-2004

UW University Ridge Research Steering Committee, 1999-2003

National Wetlands Awards Selection Committee, US EPA and Environmental Law Inst., 1997-1998

Pro Esteros, Board of Directors, 1990-91; Advisory Board 1995-8

National Parks Research Program Reviewer, Invasives in Everglades National Park, 1996-1997

Wetland Advisory Board, City of San Diego, 1992-1996

California Coastal Commission, Technical Review Committee for Developing State-Wide Standards for Mitigation Performance, 1994-2005

American Society of Civil Engineers Task Committee on Physical Processes in Tidal Wetland Restoration, 1996-98

National Wetlands Awards (Environmental Law Inst. & Environmental Protection Agency) Honorable Mention, 1994; Review panel member, 1995

U.S. Environmental Protection Agency Science Advisory Board Consultant, 1995-8
 President Clinton's Forum on Science and Technology, Invitee, March 1994
 Technical Panel, Environmental Protection Agency Global Change Program, 1993-5
 National Water Research Institute, Research Advisory Board, 1992-3
 Wetland Advisory Board, City of San Diego (Mayoral Appointee), 1992-6
 California Sea Grant College, Coastal Resources Research Coordinator, 1992-6
 Ecological Society of America ad hoc Committee on Wetlands Delineation, 1991
 City of San Diego, Famosa Slough Guidance Committee, 1991
 National Wetland Technical Council (13 members nationwide), charter member
 Review Panel, US Dept. of Agriculture Competitive Grants Program for Water Quality, 1991
 Scientific Advisory Committee, NOAA Estuarine Habitat Research Program, 1990-3
 Tijuana River National Estuarine Research Reserve, Research and Education Committee Chair,
 1982-93; Restoration Committee, 1995-8
 Public Affairs Committee, Ecological Society of America (ESA), 1988-91
 SDSU representative to the California Sea Grant Committee, 1986-90
 Los Peñasquitos Lagoon Foundation, Technical Advisory Committee, 1985-97
 Congressman Jim Bates Environment Subcommittee, 1985-6

LEAFLETS (30 well-illustrated materials that interpret research for a broad audience) at
<http://uwarboretum.org> (click on leaflets on the publications menu)

PUBLICATIONS (not including abstracts and project reports)

- Zedler, Joy B. In press. Patterns in nature and their causes. Paper Trail Essay for the Bulletin of the Ecological Society of America. (Invited).
 Healy, M. G., I. Rojas-Viada, and J. B. Zedler. In revision. Adaptive control of *Phalaris arundinacea* in Curtis Prairie.
 Doherty, J. M., J. F. Miller, S. Prellwitz, A. M. Thompson, S. Loheide, and J. B. Zedler. In review. Bundles and tradeoffs among six wetland services were associated with hydrologic regime.
 Doherty, J. M., and J. B. Zedler. In press. Dominant graminoids support restoration of productivity but not diversity in urban wetlands. *Ecological Engineering, Special issue on restoration*.
 Morzaria-Luna, H. N., and J. B. Zedler. On line Sept. 2013. Competitive interactions between two salt marsh halophytes across stress gradients. *Wetlands*.
 Zedler, J.B. In press. Achievable restoration targets for urban wetlands. *Urban Coasts*, Online journal of the Center for Santa Monica Bay Studies, Los Angeles.
 Galatowitsch, S. M. and J. B. Zedler. In press. Chapter 9. Wetland Restoration. In: D. Batzer and R. Sharitz (Eds.) *Ecology and Freshwater and Estuarine Wetlands*, 2nd edition. Elsevier, Inc., San Diego.
 Lawrence, B. A., and Zedler, J. B. 2013. Tussock structural composition and carbon storage in *Carex stricta* sedge meadows. *Wetlands*. Online.

- Zedler, J. B., and R. A. Lindig-Cisneros. 2013. Restoration of biodiversity, overview. In S. A. Levin, ed. *Encyclopedia of Biodiversity* 2nd Edition, Vol. 6:453-460. Academic Press. Waltham, Massachusetts.
- Lawrence, B., T. Fahey, and J. B. Zedler. 2013. Root dynamics of *Carex stricta*-dominated tussock meadows. *Plant and Soil* 364:325-339. DOI: 10.1007/s11104-012-1360-y
- Zedler, J. B. 2012. Chapter 1. Introduction: diverse perspectives on tidal marshes. Pp. 1-17 In A. Palaima, ed., *Ecology, Conservation, and Restoration of Tidal Marshes: The San Francisco Estuary*. University of California Press, Berkeley.
- Zedler, J. B., J. M. Doherty and N. A. Miller. 2012. Shifting restoration policy to address landscape change, novel ecosystems, and monitoring. *Ecology and Society* 17 (4): 36. [online] URL: [/www.ecologyandsociety.org/vol17/iss4/art36/](http://www.ecologyandsociety.org/vol17/iss4/art36/), also at special feature URL: www.ecologyandsociety.org/issues/view.php/feature/82.
- Johnston, C. A., and J. B. Zedler. 2012. Identifying preferential associates to initiate restoration plantings. *Restoration Ecology* 20:764-772.
- Olson, E., S. Ventura, and J. B. Zedler. 2012. Merging geospatial and field data to predict the distribution and abundance of an exotic macrophyte in a large Wisconsin reservoir. *Aquatic Botany* 96: 31-41.
- Doherty J. M., C. Callaway, and J. B. Zedler. 2011. Diversity-function relationships changed in a long-term restoration experiment. *Ecological Applications* 21: 2143-2155.
- Lawrence, B. A., and J. B. Zedler. 2011. Formation of tussocks in sedges: effects of hydroperiod and nutrients. *Ecological Applications* 21: 1745-1759.
- Zedler, J. B. 2011. Restoring a dynamic ecosystem to sustain biodiversity. *Ecological Restoration* 29:152-160.
- Zedler, J. B. 2011. Wetlands. Pp. 698-704 in D. Simberloff and M. Remanek, eds. *Encyclopedia of Introduced Invasive Species*. UC Press. Berkeley, CA.
- Jelinski, N. A., C. J. Kucharik and J. B. Zedler. 2011. A test of diversity-productivity models in natural, degraded, and restored wet prairies. *Restoration Ecology* 19:186:293).
- Zedler, J. B. 2010. How frequent storms affect wetland vegetation: A preview of climate change impacts. *Frontiers in Ecology and the Environment* 8:540-547.
- Zedler, J. B. 2010. Wetlands as harbingers of climate change. *National Wetlands Newsletter* 32: 13-17.
- Healy, M.G., and J. B. Zedler. 2010. Setbacks in replacing *Phalaris arundinacea* monotypes with sedge meadow vegetation. *Restoration Ecology* 18: 155-164.
- Allen, A. E., F. J. Santana-Michel, C. Ortiz Arrona and J. B. Zedler. 2010. Integrating ecological and ethnobotanical priorities into riparian restoration. *Ecological Restoration* 28: 377-388.
- Prasser, N., and J. B. Zedler. 2010. Salt tolerance of invasive *Phalaris arundinacea* exceeds that of native *Carex stricta* (Wisconsin). *Ecological Restoration* 28:238-240.
- Johnston, C. A., M. Tulbure, and J. B. Zedler. 2010. Latitudinal gradient of floristic condition among Great Lakes Coastal Wetlands. *Journal of Great Lakes Research* 36: 772-779.

- Hall, S. J., and J. B. Zedler. 2010. Constraints on sedge meadow self-restoration in urban wetlands. *Restoration Ecology* 5:671-680.
- Zedler, J. B. 2009. Feedbacks that might sustain natural, invaded and restored states in herbaceous wetlands. Pages 236-258 in R. Hobbs and K. N. Suding, eds., *New models for ecosystem dynamics and restoration*, Island Press, Washington, D.C.
- Larkin, D., J. West, and J. B. Zedler. 2009. Created pools and food availability for fishes in a restored salt marsh. *Ecological Engineering* 35:65-74.
- Gardner, R. C., J. Zedler, A. Redmond, R. E. Turner, C. A. Johnston, V. A. Alvarez, C. A. Simenstad, K. L. Prestegard, and W. J. Mitsch. 2009. Compensating for wetland losses under the Clean Water Act (Redux): Evaluating the Federal Compensatory Mitigation Regulation. *National Wetland Newsletter* 31(2):1, 3-8 (short, reformatted version of the following).
- Gardner, R. C., J. Zedler, A. Redmond, R. E. Turner, C. A. Johnston, V. A. Alvarez, C. A. Simenstad, K. L. Prestegard, and W. J. Mitsch. 2009. Compensating for wetland losses under the Clean Water Act (Redux): Evaluating the Federal Compensatory Mitigation Regulation. *Stetson Law Review* 38:213-249.
- Johnston, C. A., Joy B. Zedler, M. G. Tulbure, C. B. Frieswyk DeJong, B. L. Bedford, L. Vaccaro. 2009. A unifying approach for evaluating the condition of wetland plant communities and identifying related stressors. *Ecological Applications* 19:1739-1957.
- Callaway, J. C., and J. B. Zedler. 2009. Salt marsh conservation along the leading edge of the continent. Pp. 285-307 in B. Silliman, E. Grosholz and M. Bertness, eds. *Human impacts on Salt Marshes*. University of California Press, Berkeley, CA.
- Zedler, J. B. and J. M. West. 2008. Declining diversity in natural and restored salt marshes: A 30-year study of Tijuana Estuary. *Restoration Ecology* 16:249-262.
- Frieswyk, C. B., C. Johnston, and J. B. Zedler. 2008. Identifying and characterizing dominant plants as an indicator of community condition. *Journal of Great Lakes Research* 33(Special Issue 3):125-135.
- Adam, P., M. D. Bertness, A. J. Davy, and J. B. Zedler. 2008. Saltmarsh. Pp. 157-171 in N. Polunin, ed. *Aquatic Ecosystems*. Cambridge University Press. Cambridge, U.K.
- Johnston, C.A., B. Bedford, M. Bourdaghs, T. Brown, C. B. Frieswyk, M. Tulbure, L. Vaccaro, and J. B. Zedler. 2008. Plant species indicators of physical environment in Great Lakes coastal wetlands. *Journal of Great Lakes Research* 33 (Special Issue 3):106-124.
- Johnston, C.A., D. Ghioca, M. Tulbure, SB. L. Bedford, M. Bourdaghs, C. B. Frieswyk, L. Vacaro, and J. B. Zedler. 2008. Partitioning vegetation response to anthropogenic stress to develop multi-taxa indicators of wetland condition. *Ecological Applications* 18:983-1001.
- Varty, A., and J. B. Zedler. 2008. How waterlogged microsites help an annual plant persist among salt marsh perennials. *Estuaries and Coasts* 31:300-312.
- Stiles, C. A., B. Bemis, and J. B. Zedler. 2008. Evaluating edaphic conditions favoring reed canary grass invasion in a restored native prairie. *Ecological Restoration* 26:61-70.
- Zedler, J. B., and K. Potter. 2008. Southern Wisconsin's Herbaceous Wetlands: Their Recent History and Precarious Future. Pages 193-210 in *The vanishing present*. D. Waller and T. Rooney, eds. University of Chicago Press.

- Larkin, D. J., S. P. Madon, J. M. West and J. B. Zedler. 2008. Topographic heterogeneity influences fish use of an experimentally-restored tidal marsh. *Ecological Applications* 18:483-496.
- Zedler, J. B., C. L. Bonin, D. J. Larkin, and A. Varty. 2008. Salt marshes. Pages 3132-3141 in Sven Erik Jorgensen & Brian D. Fath, 2008. *Encyclopedia of Ecology*, 1st Edition, Elsevier B.V., Oxford.
- Boers, A. M., and J. B. Zedler. 2008. Stabilized water levels and *Typha* invasiveness. *Wetlands* 28: 676-685.
- Wagner, K., S. K. Gallagher, M. Hayes, B. A. Lawrence, and J. B. Zedler. 2008. Wetland restoration in the new millennium: Do research efforts match opportunities? *Restoration Ecology* 16: 367-372.
- Hall, S. J., R. A. Lindig-Cisneros and J. B. Zedler. 2008. Does harvesting sustain plant diversity in Central Mexican wetlands? *Wetlands* 28:776-792.
- Peterson, C. H., K. W. Able, C. F. DeJong, M. F. Piehler, C. A. Simenstad, and J. B. Zedler. 2008. Practical proxies for tidal marsh ecosystem services: Application to injury and restoration. *Advances In Marine Biology* 54:221-266.
- Committee on the St. Lawrence Seaway: Options to Eliminate Introduction of Nonindigenous Species into the Great Lakes, Phase 2; National Research Council. 2008. *Great Lakes Shipping, Trade, and Aquatic Invasive Species*. Transportation Research Board, Washington, D.C. (Member of this NRC Committee).
- Bonin, C. L., and J. B. Zedler. 2008. Plant traits and plasticity help explain abundance ranks in a California salt marsh. *Estuaries and Coasts* 31:682-693.
- Boers, A., R. Veltman, and J. B. Zedler. 2007. *Typha x glauca* dominance and extended hydroperiod constrain restoration of wetland diversity. *Ecological Engineering* 29:232-244.
- Morzaria-Luna, H., and J. B. Zedler. 2007. Does seed availability limit plant establishment during salt marsh restoration? *Estuaries* 30:12-25.
- Frieswyk, C. B., and J. B. Zedler. 2007. Vegetation change in Great Lakes coastal wetlands: Deviation from the historical cycle. *Journal of Great Lakes Research* 33:366-380.
- Kercher, S. M., A. Herr-Turoff, and J. B. Zedler. 2007. Understanding invasion as a process: The case of *Phalaris arundinacea* in wet prairies. *Biological Invasions* 9:657-665.
- Zedler, J. B. 2007. Success: An unclear, subjective descriptor of restoration outcomes. *Ecological Restoration* 25:162-168.
- Wilcox, J. C., M. T. Healy and J. B. Zedler. 2007. Restoring native vegetation to an urban wet meadow dominated by reed canarygrass (*Phalaris arundinacea* L.) in Wisconsin, USA. *Natural Areas Journal* 27:354-365.
- Sullivan, G., J. Callaway and J. B. Zedler. 2007. Plant assemblage composition explains and predicts how biodiversity affects salt marsh functioning. *Ecological Monographs* 77:569-590.
- Herr-Turoff, A. and J. B. Zedler. 2007. Does morphological plasticity of the *Phalaris arundinacea* canopy increase invasiveness? *Plant Ecology* 193:265-277.
- O'Brien, E., and J. B. Zedler. 2006. Accelerating the restoration of vegetation in a southern California salt marsh. *Wetlands Ecology and Management* 14:269-286.

- Larkin, D. J., G. Vivian-Smith, and J. B. Zedler. 2006. Topographic heterogeneity theory and ecological restoration. Pp. 144-164 In: Falk, D., M. Palmer, and J. B. Zedler, eds. *Foundations of Restoration Ecology*. Island Press, Washington, D.C.
- Falk, D., M. Palmer, and J. B. Zedler, eds. 2006. *Foundations of Restoration Ecology*. Island Press. Washington, D.C.
- Palmer, M. A., D. A. Falk, and J. B. Zedler. 2006. Ecological theory and restoration ecology. Pp 1-10 In: Falk, D., M. Palmer, and J. B. Zedler, eds. *Foundations of Restoration Ecology*. Island Press, Washington D.C.
- Falk, D. A., M. A. Palmer, and J. B. Zedler. 2006. Integrating restoration ecology and ecological theory: A synthesis. Pp. 341-345 In: Falk, D., M. Palmer, and J. B. Zedler, eds. *Foundations of Restoration Ecology*. Island Press. Washington D.C.
- Peach, M. A. and J. B. Zedler. 2006. How tussocks structure sedge meadow vegetation. *Wetlands* 26: 322-335.
- Boers, A., C. Frieswyk, J. Verhoeven and J. Zedler. 2006. Chapter 10: Contrasting approaches to the restoration of diverse vegetation in herbaceous wetlands. Pp. 225-246 in R. Bobbink, B. Beltman, J. J. T. A. Verhoeven, and D. F. Whigham, eds. *Wetlands as a natural resource*, Vol. 2. *Wetlands: Functioning, Biodiversity Conservation and Restoration*. Springer Verlag.
- Zedler, J. 2006. Wetland restoration. Pp. 348-406 in D. P. Batzer and R. R. Sharitz, eds. *Ecology of Freshwater and Estuarine Wetlands*. Elsevier, Inc., San Diego.
- Frieswyk, C. B., and J. B. Zedler. 2006. Do seed banks confer resilience to coastal wetlands invaded by *Typha x glauca*? *Canadian Journal of Botany* 84:1882-1893.
- Callaway, J. C., K. W. Wallace and J. B. Zedler. 2006. Reply to comment on our paper Evolution of tidal creek networks in a high sedimentation environment: a 5-year experiment at Tijuana Estuary, California. *Estuaries and Coasts* 29:1268-1269.
- Zedler, J. B. 2005. Restoring wetland plant diversity: A comparison of existing and adaptive approaches. *Wetlands Ecology and Management* 13:5-14.
- Fellows, M. and J. B. Zedler. 2005. Effects of the non-native grass, *Parapholis incurva* (Poaceae), on the rare and endangered hemiparasite, *Cordylanthus maritimus* subsp. *maritimus* (Scrophulariaceae). *Madroño* 52:91-98.
- Zedler, J. B. 2005. Restoration ecology: Principles from field tests of theory. *San Francisco Estuary and Watershed Science*. On line at:
<http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art4>
- Zedler, J. B. 2005. How compatible are biodiversity and ecosystem-service restoration goals? *National Wetlands Newsletter* 27(6):1,11-13,19.
- Herr-Turoff, A., and J. B. Zedler. 2005. Does wet prairie vegetation retain more nitrogen with or without *Phalaris* invasion. *Plant and Soil* 277:19-34.
- Lindig-Cisneros, R. y J. B. Zedler. La restauración de humedales. 2005. Pp. 201-213 In: Sánchez, Ó., E. Peters, R. Márquez-Huitzil, E. Vega, G. Portales, M. Valdés y D. Azuara, eds. *Temas Sobre Restauración ecológica*. Instituto Nacional de Ecología-Semarnat. U.S. Fish and Wildlife Service, Unidos para la Conservación. México, D. F.

- Wallace, K.J., J.C. Callaway, and J.B. Zedler. 2005. Evolution of tidal creek networks in a high sedimentation environment: A 5-year experiment at Tijuana Estuary, California. *Estuaries* 28:795-811.
- Zedler, J. B., and S. Kercher. 2005. Wetland resources: Status, ecosystem services, degradation, and restorability. *Annual Review of Environment and Resources* 30:39-74. Annual Reviews, Palo Alto, CA.
- Kercher, S. M., and J. B. Zedler. 2004. Multiple disturbances accelerate invasion of reed canary grass (*Phalaris arundinacea* L.) in a mesocosm study. *Oecologia* 138:455-464.
- Zedler, J. B. 2004. Compensatory mitigation for damages to wetlands: Can net losses be reduced? *Transactions of the Wisconsin Academy of Arts, Letters and Sciences* 90:103-117.
- Callaway, J. C. and J. B. Zedler. 2004. Restoration of urban salt marshes: Lessons from southern California. *Urban Ecosystems* 7:107-124.
- Morzaria-Luna, H., J. C. Callaway, G. Sullivan and J. B. Zedler. 2004. Relationship between topographic heterogeneity and vegetation patterns in a Californian salt-marsh. *Journal of Vegetation Science*.15:523-530.
- Kercher, S. M., Q. Carpenter, and J. B. Zedler. 2004. Interrelationships of hydrologic disturbances, reed canary grass (*Phalaris arundinacea* L.), and native plants in Wisconsin wet meadows. *Natural Areas Journal* 24:316-325.
- Zedler, J. B., and S. Kercher. 2004. Causes and consequences of invasive plants in wetlands: Opportunities, opportunists, and outcomes *Critical Reviews in Plant Sciences* 23:431-452.
- Kercher, S. M., and J. B. Zedler. 2004. Flood tolerance in wetland angiosperms: a comparison of invasive and noninvasive species. *Aquatic Botany* 80:89-102.
- Zedler, J. B. 2004. Compensating for wetland losses in the United States. In M. M. Rehfisch, C. F. Feare, N. V. Jones, and C. Spray, eds. *Climate Change and Coastal Birds*. *Ibis* 146 (Suppl. 1): S92-S100.
- Zedler, J. B., and J. C. Callaway. 2003. Adaptive restoration: A strategic approach for integrating research into restoration projects. Pp. 167-174 in D. J. Rapport, W. L. Lasley, D. E. Rolston, N. O. Nielsen, C. O. Qualset, and A. B. Damania, eds. *Managing for Healthy Ecosystems*. Lewis Publishers, Boca Raton, Florida.
- Zedler, J. B. 2003. Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and Environment* 1:65-72.
- Ward, K. M., J. C. Callaway, and J. B. Zedler. 2003. Episodic colonization of an intertidal mudflat by a native cordgrass (*Spartina foliosa*) at Tijuana Estuary. *Estuaries* 26:116-130.
- Lindig-Cisneros, R., J. Desmond, K. Boyer, and J. B. Zedler. 2003. Wetland restoration thresholds: Can a degradation transition be reversed with increased effort? *Ecological Applications* 13:193-205.
- Miller, R. C., and J. B. Zedler. 2003. Responses of native and invasive wetland plants to hydroperiod and water depth. *Plant Ecology* 167:57-69.
- Zedler, J. B., H. N. Morzaria-Luna, and K. Ward. 2003. The challenge of restoring vegetation on tidal, hypersaline substrates. *Plant and Soil* 253:259-273.

- Maurer, D. A., R. Lindig-Cisneros, K. J. Werner, S. Kercher, R. Miller, and J. B. Zedler. 2003. The replacement of wetland vegetation by *Phalaris arundinacea* (reed canary grass). *Ecological Restoration* 21:116-119.
- West, J., Williams, G., Madon, S. P., and Zedler, J. B. 2003. Integrating spatial and temporal variability into the analysis of fish food web linkages in Tijuana Estuary. *Environmental Biology of Fishes* 67:297-309.
- Meyer, J. L., L. A. Kaplan, D. Newbold, D. L. Strayer, C. J. Woltemade, J. B. Zedler, R. Beilfuss, Q. Carpenter, R. Semlitsch, M. C. Watzin, and P. H. Zedler. 2003. Where rivers are born: The scientific imperative for defending small streams and wetlands. White paper. The Sierra Club, Washington, D. C.
- Callaway, J. C., G. Sullivan, and J. B. Zedler. 2003. Species-rich plantings increase biomass and nitrogen accumulation in a wetland restoration experiment. *Ecological Applications* 13:1626-1639.
- Kercher, S. M., C. B. Frieswyk, and J. B. Zedler. 2003. Effects of sampling teams and estimation methods on the assessment of plant cover. *Journal of Vegetation Science* 14:899-906.
- Bonilla-Warford, C., and J. B. Zedler. 2002. Potential for using native plant species in stormwater wetlands. *Environmental Management* 29:385-393.
- Keer, G., and J. B. Zedler. 2002. Salt marsh canopy architecture differs with the number and composition of species. *Ecological Applications* 12:456-473.
- Maurer, D. A., and J. B. Zedler. 2002. Differential invasion of a wetland grass explained by tests of nutrients and light availability on establishment and vegetative growth. *Oecologia* 131:279-288.
- Lindig-Cisneros, R. and J. B. Zedler. 2002. *Phalaris arundinacea* L. seedling establishment: Effects of canopy complexity in fen, mesocosm and restoration experiments. *Canadian Journal of Botany* 80:617-624.
- Madon, S. P., J. West, and J. B. Zedler. 2002. Responses of fish to topographic heterogeneity in an experimental marsh (California). *Ecological Restoration* 20:56-58.
- Zedler, J. B., and Paul Adam. 2002. Saltmarshes Pp. 238-266 in M. Perrow and A. Davy, ed. *Handbook of Restoration Ecology*, Cambridge: Cambridge University Press. Cambridge, UK.
- Lindig-Cisneros, R. and J. B. Zedler. 2002. Relationships between canopy complexity and germination microsites for *Phalaris arundinacea* L. *Oecologia* 133:159-167.
- Desmond, J., D. Deutschman, and J. B. Zedler. 2002. Spatial and temporal variation in estuarine fish and invertebrate assemblages: Analysis of an 11-year dataset. *Estuaries* 25:552-569.
- Woo, I., and J. B. Zedler. 2002. Can nutrients alone shift a sedge meadow towards the invasive *Typha x glauca*? *Wetlands* 22:509-521.
- Werner, K. J. and J. B. Zedler. 2002. How sedge meadow soils, microtopography, and vegetation respond to sedimentation. *Wetlands* 22:451-466.
- Lindig-Cisneros, R. and J. B. Zedler. 2002. Halophyte recruitment in a salt marsh restoration site. *Estuaries* 25: 1174-1183.
- Zedler, J. B., editor. 2001. *Handbook for Restoring Tidal Wetlands*. Marine Science Series, CRC Press LLC, Boca Raton. Florida.

- Zedler, J. B., R. Lindig-Cisneros, C. Bonilla-Warford, and I. Woo. 2001. Restoration of biodiversity: An overview. Pp. 203-212 in S. Levin, editor. *Encyclopedia of Biodiversity*, Vol. 5.. Academic Press, San Diego.
- Noe, G. B., and J. B. Zedler. 2001. Spatio-temporal variation of salt marsh seedling establishment in relation to the abiotic and biotic environment. *Journal of Vegetation Science* 12:61-74.
- Noe, G. B., and J. B. Zedler. 2001. Variable precipitation limits the germination of upper intertidal marsh plants in southern California. *Estuaries* 24:30-40.
- Madon, S. P., G. D. Williams, J. M. West, and J. B. Zedler. 2001. The importance of marsh access to growth of the California killifish, *Fundulus parvipinnis*, evaluated through bioenergetics modeling. *Ecological Modelling* 136: 149-165.
- Williams, G. D., J. M. West, and J. B. Zedler. 2001. Shifts in fish and invertebrate assemblages of two southern California estuaries during the 1997-98 El Niño. *Bulletin of the Southern California Academy of Sciences* 100(3): 212-237.
- Goodwin, P., A. J. Mehta, and J. B. Zedler. 2001. Tidal wetland restoration: An introduction. *Journal of Coastal Research Special Issue* 27:1-6.
- Zedler, J. B., and J. C. Callaway. 2001. Tidal wetland functioning. In P. Goodwin and A. J. Mehta, eds. *Tidal Wetlands; Physical and Ecological processes. Journal of Coastal Research Special Issue* 27:38-64.
- Zedler, J. B., and R. Lindig-Cisneros. 2001. Functional equivalency of restored and natural salt marshes. Pp. 565-582 in M. Weinstein and D. Kreeger, eds. *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Zedler, J. B., and L. Shabman. 2001. Compensatory mitigation needs improvement, panel says. *National Wetlands Newsletter* 23(4):1, 12-14. [Also reprinted in *Ecological Restoration*, November 2001.]
- McCarty, J. P., and J. B. Zedler. 2001. Ecological restoration and its potential to reduce the negative impacts of global change. Pp. 532-539 in H. A. Mooney and J. Canadell, eds. *Encyclopedia of Global Environmental Change*, Vol. 2: The Earth System: Biological and Ecological Dimensions of Global Environmental Change. John Wiley and Sons Ltd., London.
- Lindig-Cisneros, R. A., and J. B. Zedler. 2001. Effect of light on *Phalaris arundinacea* L. germination. *Plant Ecology* 155:75-78.
- Turner, R. E., A. Redmond, and J. B. Zedler. 2001. Count it by acre or function—Mitigation adds up to net loss of wetlands. *National Wetlands Newsletter* 23(6):5-6,14-16.
- Zedler, J. B., J. C. Callaway, and G. Sullivan. 2001. Declining biodiversity: Why species matter and how their functions might be restored. *BioScience* 51:1005-1017.
- Committee on Wetland Mitigation; National Research Council. 2001. *Compensating for Wetland Loss under the Clean Water Act*. National Academy Press, Washington, D.C. (Coauthor of this book and chair of the panel that produced it).
- James, M. L., and J. B. Zedler. 2000. Dynamics of wetland and upland subshrubs at the salt marsh-coastal sage scrub ecotone. *American Midland Naturalist* 82:81-99.

- Zedler, J. B. 2000. Restoration of biodiversity to coastal and inland wetlands. Pp. 311-330 in B. Gopal, editor. *Biodiversity in Wetlands: Assessment, Function and Conservation*. Backhuys Publishers, Leiden, The Netherlands.
- Zedler, J. B., and J. C. Callaway. 2000. Evaluating the progress of engineered tidal wetlands. *Ecological Engineering* 15:211-225.
- Desmond, J. S., G. D. Williams, and. B. Zedler 2000. Improving the design of fish habitat mitigation projects in southern California. Pages 245-251. In J. E. Keeley, M. Baer-Keeley, and C.J. Fotheringham, eds. 2nd Interface Between Ecology and Land Development in California. US Geological Survey Open File Report 00-62. Sacramento, California.
- Streever, W., and J. B. Zedler. 2000. To plant or not to plant? *BioScience* 50:188-189.
- Zedler, J. B. 2000. Progress in wetland restoration ecology. *Trends in Ecology and Evolution* 15:402-407 (invited review article).
- Trnka, S., and J. B. Zedler. 2000. Site conditions, not parental phenotype, determine the height of *Spartina foliosa*. *Estuaries* 23:572-582..
- Lindig-Cisneros, R. and J. B. Zedler. 2000. Restoring urban habitats: A comparative approach. *Ecological Restoration* 18:184-192.
- West, J. M., and J. B. Zedler. 2000. Marsh-creek connectivity: Fish use of a tidal salt marsh in southern California. *Estuaries* 23: 699-710.
- Noe, G. B., and J. B. Zedler. 2000. Differential effects of four abiotic factors on the germination of salt marsh annuals. *American Journal of Botany* 87:1679-1692.
- Boyer, K. E., J. C. Callaway, and J. B. Zedler. 2000. Evaluating the progress of restored cordgrass (*Spartina foliosa*) marshes: Belowground biomass and tissue N. *Estuaries* 23:711-721.
- Fong, P., and J. B. Zedler. 2000. Sources, sinks, and fluxes of nutrients (N+P) in a small highly modified urban estuary in southern California. *Urban Ecosystems* 4:125-144.
- Desmond, J., J. B. Zedler, and G. D. Williams. 2000. Fish use of tidal creek habitats in two southern California salt marshes. *Ecological Engineering*. 14:233-252
- Sullivan, G., and J. B. Zedler. 1999. Functional redundancy among tidal marsh halophytes: a test. *Oikos* 84: 246-260.
- Zedler, J. B., J. C. Callaway, J. Desmond, G. Vivian-Smith, G. Williams, G. Sullivan, A. Brewster, and B. Bradshaw. 1999. Californian salt marsh vegetation: An improved model of spatial pattern. *Ecosystems* 2:19-35.
- Boyer, K. E., and J. B. Zedler. 1999. Nitrogen addition could shift species composition in a restored California salt marsh. *Restoration Ecology* 7:74-85.
- Zedler, J. B., and J. C. Callaway. 1999. Tracking wetland restoration: Do mitigation sites follow desired trajectories? *Restoration Ecology* 7:69-73.
- Zedler, J. B. 1999. The ecological restoration spectrum. Pp. 301-318 in W. Streever, ed. An International Perspective on Wetland Rehabilitation. Kluwer Academic Press, Dordrecht, The Netherlands.
- Zedler, J. B., K. E. Boyer, G. D. Williams, and J. C. Callaway. 1999. Creating intertidal habitat for endangered species in southern California: Achievements and challenges. Pp. 739-747 in A. J. McComb and J. A. Davis, eds. *Wetlands for the Future*. Proceedings of INTECOL's V International Wetlands Conference, Gleneagles Press, Adelaide.

- Williams, G. D., and J. B. Zedler. 1999. Fish assemblage composition in constructed and natural tidal marshes of San Diego Bay: Relative influence of channel morphology and restoration history. *Estuaries* 22:702-716.
- Zedler, J. B. 1999. The continuing challenge of restoration. Pages 116-126 in C. Meine and R. I. Knight, eds. *The essential Aldo Leopold*. University of Wisconsin Press, Madison.
- Zedler, J. B., J. S. Desmond, S. Phinn, B. Nyden, G. Sullivan, G. D. Williams, J. C. Callaway, K. E. Boyer, A. Powell. 1998. New tools for assessing coastal habitats. Pp. 1016-1027 in O. T. Magoon, H. Converse, B. Baird, and M. Miller-Henson, eds. *California and the World Ocean '97*. American Society of Civil Engineers, Reston, Virginia.
- Zedler, J. B. 1998. Replacing endangered species habitat: The acid test of wetland ecology. Pp. 364-379 (Chapter 15) in P. L. Fiedler and P. M. Kareiva, eds. *Conservation biology for the coming age*. Chapman and Hall, New York.
- Zedler, Joy B., and Naomi Rea. 1998. Introduction to the ecology and management of wetland plant invasions. *Wetlands Ecology and Management* 5:161-163.
- Callaway, J. C., and J. B. Zedler. 1998. Interactions between a salt marsh native perennial (*Salicornia virginica*) and an exotic annual (*Polypogon monspeliensis*) under varied salinity and hydroperiod. *Wetlands Ecology and Management* 5:179-194.
- Boyer, K. E., and J. B. Zedler. 1998. Effects of nitrogen additions on the vertical structure of a constructed cordgrass marsh. *Ecological Applications* 8:692-705.
- Zedler, J. B. 1998. Southern California Coastal Marshes. Pp. 37-38 in S. Sanzione and A. McElroy, eds. *Ecological impacts and evaluation criteria for the use of structures in marsh management*. U.S. Environmental Protection Agency Sciences Advisory Board. EPA-SAB-EPEC-98-003.
- Zedler, J. B., M. Fellows, and S. Trnka. 1998. Wastelands to wetlands: Links between habitat protection and ecosystem science. Pp. 69-112 in P. Groffman and M. Pace, eds. *Successes, limitations and frontiers in ecosystem science*. Springer-Verlag, New York.
- Williams, G. D., J. S. Desmond, and J. B. Zedler. 1998. Extension of two nonindigenous fishes, *Acanthogobius flavimanus* and *Poecilia latipinna*, into San Diego Bay marsh habitats. *California Fish and Game* 84(1):1-17.
- Zedler, J. B., and M. K. Leach. 1998. Managing urban wetlands for multiple use, including research. *Urban Ecosystems* 2:189-204.
- Zedler, J. B. 1997. Conservation activism: A proper role for academics? In S. T. A. Pickett, R. S. Ostfeld, M. Shachak, and G. E. Likens, eds. *The ecological basis of conservation*. P. 345-350. Chapman and Hall. NY.
- Zedler, J. B., and J. C. Callaway. 1997. Restoration Ecology: Combining the teaching of ecological principles with team experiments and native plant restoration on the SDSU campus. *Bull. Ecol. Soc. Amer.* 78:67-69.
- Parsons, L., and J. B. Zedler. 1997. Factors affecting reestablishment of an endangered annual plant at a California salt marsh. *Ecological Applications* 7:253-267.
- Zedler, J. B., G. D. Williams, and J. Desmond. 1997. Wetland mitigation: Can fishes distinguish between natural and constructed wetlands? *Fisheries* 22:26-28.

- Haltiner, J., J.B. Zedler, K.E. Boyer, G.D. Williams, and J.C. Callaway. 1997. Influence of physical processes on the design, functioning and evolution of restored tidal wetlands in California. *Wetlands Ecology and Management* 4:73-91.
- Kwak, T. J., and J. B. Zedler. 1997. Food web analysis of southern California coastal wetlands using multiple stable isotopes. *Oecologia* 110: 262-277.
- Kuhn, N., and J. B. Zedler. 1997. Differential effects of salinity and soil saturation on native and exotic plants of a coastal salt marsh. *Estuaries* 20:391-403.
- Callaway, J.C., J.B. Zedler, and D.L. Ross. 1997. Using tidal salt marsh mesocosms to aid wetland restoration. *Restoration Ecology* 5:135-146.
- Fong, P., J. Desmond, and J.B. Zedler. 1997. The effect of a horn snail on *Ulva expansa*: consumer or facilitator of growth? *Journal of Phycology* 33:353-359.
- Zedler, J. B. 1997. Adaptive management of coastal ecosystems designed to support endangered species. *Ecology Law Quarterly* 24:735-743.
- Zedler, J. B. 1996. Ecological issues in wetland mitigation: An introduction to the forum. *Ecological Applications* 6:33-37.
- Zedler, J. B. 1996. Coastal mitigation in southern California: The need for a regional restoration strategy. *Ecological Applications* 6:84-93.
- Boyer, K. E. and J. B. Zedler. 1996. Damage to cordgrass by scale insects in a constructed salt marsh: effects of nitrogen additions. *Estuaries* 19:1-12.
- Zedler, J. B. 1996. Ecological function and sustainability in created wetlands. P. 331-342 in D. Falk, C. Millar, and P. Olwell, eds. *Restoring diversity: Strategies for reintroduction of endangered plants*. Island Press.
- Scatolini, S. R., and J. B. Zedler. 1996. Epibenthic invertebrates of natural and constructed marshes of San Diego Bay. *Wetlands* 16:24-37.
- Zedler, J. B., principal author. 1996. *Tidal wetland restoration: A scientific perspective and southern California focus*. California Sea Grant College System, University of California, La Jolla, California Report No. T-038. 129 p.
- Phinn, S. R., D. A. Stow, and J. B. Zedler. 1996. Monitoring wetland habitat restoration in southern California using airborne digital multispectral video data. *Restoration Ecology* 4:412-422.
- Fong, P., K. Boyer, J. Desmond, and J. B. Zedler. 1996. Salinity stress, N competition, and facilitation: What controls seasonal succession of two opportunistic green macroalgae? *J. Experimental Marine Biology and Ecology* 206:203-221.
- Zedler, J. B., P. Nelson, and P. Adam. 1995. Plant community organization in New South Wales saltmarshes: species mosaics and potential causes. *Wetlands (Australia)* 14:1-18.
- Zedler, J. B. 1995. Reinventing wetland science. *National Wetlands Newsletter* 17(4):1, 17-20
- Zedler, J. B., and B. Nyden. 1995. Innovative management of California wetlands. *Forum for Applied Research and Public Policy* 10:93-97.
- Committee on Characterization of Wetlands; National Research Council. 1995. *Wetlands: Characteristics and Boundaries*. National Academy Press, Washington, D.C. (Coauthor of this 306-page book).

- Phinn, S. R., D. A. Stow, and J. B. Zedler. 1995. Monitoring wetland habitat restoration using airborne digital multi-spectral video data in southern California. Third Thematic Conference on Remote Sensing for Coastal and Marine Environments, Seattle, WA. Vol. I:322-333.
- Fong, P., T. C. Foin, and J. B. Zedler. 1994. A simulation model of lagoon algae based on nitrogen competition and internal storage. *Ecological Monographs* 64:225-247.
- Zedler, J. B. 1994. Coastal wetlands: Multiple management problems in southern California. Pp. 107-123 in *Environmental Science in the Coastal Zone: Issues for Further Research*. Proceedings of a June 1992 retreat held by the Commission on Geosciences, Environment and Resources, National Research Council. National Academy Press, Washington, DC.
- Zedler, Joy B. 1994. Restoring a nation's wetlands: why, where, and how? Pp. 417-418 in G. K. Meffe and C. R. Carroll. *Principles of Conservation Biology*. Sinauer Associates, Inc. Sunderland, Massachusetts.
- Gibson, K. D., J. B. Zedler, and R. Langis. 1994. Limited response of cordgrass (*Spartina foliosa*) to soil amendments in constructed salt marshes. *Ecological Applications* 4:757-767.
- Zedler, J. B., M. Busnardo, T. Sinicrope, R. Langis, R. Gersberg, and S. Baczkowski. 1994. Pulsed-discharge wastewater wetlands: the potential for solving multiple problems by varying hydroperiod. Pp. 363-368 in W. Mitsch, ed., *Global wetlands: Old world and new*. Elsevier, Amsterdam.
- Zedler, J. B. 1994. Salt marsh restoration: lessons from California. Pp. 75-95 in J. Cairns, ed. *Rehabilitating damaged ecosystems*, 2nd ed. CRC Press, Boca Raton, Fla. (Invited revision of 1988 chapter).
- Gersberg, R. M., D. Dodge, L. Parsons, and J. B. Zedler. 1994. Microbial water quality of the Tijuana Estuary. *Border Health* July/August/September 1994:16-27.
- Zedler, Joy B. 1993. Restoring biodiversity to coastal salt marshes. Pp. 253-258 in J. E. Keeley, ed. *Interface between ecology and land development in California*. Southern California Academy of Sciences 1992 Symposium Proceedings. Southern California Academy of Sciences, Los Angeles, California.
- Zedler, J. B. 1993. Canopy architecture of natural and planted cordgrass marshes: Selecting habitat evaluation criteria. *Ecological Applications* 3:123-138.
- Fong, P., J. B. Zedler, and R. M. Donohoe. 1993. Nitrogen vs. phosphorus limitation of algal biomass in shallow coastal lagoons. *Limnol. Oceanogr.* 38:906-923.
- Zedler, J. B. 1993. Lessons on preventing overexploitation? *Ecological Applications* 3:577-579.
- Zedler, J. B., and A. Powell. 1993. Problems in managing coastal wetlands: Complexities, compromises, and concerns. *Oceanus* 36(2):19-28.
- Fong, P., R. M. Donohoe, and J. B. Zedler. 1993. Competition with macroalgae and benthic cyanobacterial mats limits phytoplankton abundance in experimental microcosms. *Mar. Ecol. Prog. Ser.* 100:97-102.
- Fong, P., and J. B. Zedler. 1993. Temperature and light effects on the seasonal succession of algal communities in shallow coastal lagoons. *J. Exp. Mar. Biol. & Ecol.* 171:259-272.

- Fong, P., R. M. Donohoe, and J. B. Zedler. 1993. Nutrient concentration in tissue of the macroalga *Enteromorpha* as a function of nutrient history: an experimental evaluation using field microcosms. *Mar. Ecol. Prog. Ser.* 106:273-281.
- Committee on Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy; National Research Council. 1992. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. National Academy Press, Washington, D.C. (Coauthor of this 550-page book).
- Zedler, Joy B., Christopher S. Nordby, and Barbara E. Kus. 1992. *The ecology of Tijuana Estuary: A National Estuarine Research Reserve*. NOAA Office of Coastal Resource Management, Sanctuaries and Reserves Division, Washington, D.C.
- Zedler, J. B. 1992. Invasive exotic plants: Threats to coastal biodiversity. Pp. 49-62 in Proceedings, Southern California Academy of Sciences "Marine Environment of Southern California" Symposium, University of Southern California, May 1991. USC Sea Grant, Los Angeles.
- Busnardo, M. J., R. M. Gersberg, R. Langis, T. L. Sinicrope, and J. B. Zedler. 1992. Nitrogen and phosphorus removal by wetland mesocosms subjected to different hydroperiods. *Ecological Engineering* 1:287-307.
- Sinicrope, T. L., R. Langis, R. M. Gersberg, M. J. Busnardo, and J. B. Zedler. 1992. Metal removal by wetland mesocosms subjected to different hydroperiods. *Ecological Engineering* 1:309-322.
- Zedler, Joy B. 1992. Restoring cordgrass marshes in southern California. Chapter 1, pp. 7-51. In G. W. Thayer, ed. *Restoring the Nation's Marine Environment*. Maryland Sea Grant College, College Park, Maryland.
- Bedford, B. L. M. Brinson, R. Sharitz, A. van der Valk, J. Zedler. 1992. Evaluation of proposed revisions to the 1989 "Federal Manual for Identifying and Delineating Jurisdictional Wetlands." *Bull. Ecol. Soc. Amer.* 73:14-23.
- Langis, R., M. Zalejko, and J. B. Zedler. 1991. Nitrogen assessments in a constructed and a natural salt marsh of San Diego Bay, California. *Ecological Applications* 1:40-51.
- Nordby, C. S., and J. B. Zedler. 1991. Responses of fishes and benthos to hydrologic disturbances in Tijuana Estuary and Los Peñasquitos Lagoon, California. *Estuaries* 14:80-93.
- Zedler, J. B. 1991. The challenge of protecting endangered species habitat along the southern California coast. *Coastal Management* 19:35-53.
- Zedler, J. B., and R. Langis. 1991. Comparisons of constructed and natural salt marshes of San Diego Bay. *Restoration & Management Notes* 9(1):21-25.
- Zedler, J. B. 1991. Catastrophic events and interannual variability. Pp 195-201 IN P. L. Abbott and W. J. Elliott, eds. *Environmental Perils*. San Diego Association of Geologists. San Diego.
- Zedler, J., E. Paling, and A. McComb. 1990. Differential salinity responses help explain the replacement of native *Juncus kraussii* by *Typha orientalis* in Western Australian salt marshes. *Australian J. of Ecology* 15:57-72.
- Fink, B. H., and J. B. Zedler. 1990. Stress tolerance studies of dune perennials. *Madroño* 37:200-213.

- Pacific Estuarine Research Laboratory (PERL). 1990. *A manual for assessing restored and natural coastal wetlands with examples from southern California*. California Sea Grant Report No. T-CSGCP-021. La Jolla, California. (Principal author with sections by René Langis.) 105pp.
- Loucks, O., D. Buffington, J. Reisa, and J. Zedler. 1990. ESA research agenda for the 1990's. Ecological Society of America, *Applied Ecology Section Newsletter* 18:1-3.
- Fink, B. H., and J. B. Zedler. 1989. Endangered plant recovery: Experimental approaches with *Cordylanthus maritimus* ssp. *maritimus*. Pp. 460-468 in H. G. Hughes and T. M. Bonnicksen, eds. *Proceedings, First Annual Meeting of the Society of Ecological Restoration and Management*. Madison, Wisconsin.
- Zedler, J. B., R. Langis, J. Cantilli, M. Zalejko, and S. Rutherford. 1989. Assessing the successful functioning of constructed salt marshes. Pp. 311-318 in H. G. Hughes and T. M. Bonnicksen, eds. *Proceedings, First Annual Meeting of the Society of Ecological Restoration and Management*. Madison, Wisconsin.
- Zedler, J. 1989. Salt marsh communities. *ZooNooz*. Zoological Society of San Diego. 62:9-13.
- Zedler, J. B., and M. W. Weller. 1989. Overview and future directions. Pp. 465-473 in J. Kusler and M. Kentula, eds. *Wetland Creation and Restoration: the status of the science*. Vol. I, Regional Reviews. EPA/600/3-89/038a, Environmental Research Laboratory, Corvallis, Oregon.
- Josselyn, M., J. Zedler, and T. Griswold. 1989. Wetland mitigation along the Pacific Coast of the United States. Pp. 1-35 in J. Kusler and M. Kentula, eds. *Wetland Creation and Restoration: the status of the science*. Vol. I, Regional Reviews. EPA/600/3-89/038a, Environmental Research Laboratory, Corvallis, Oregon.
- Onuf, C. P., and J. B. Zedler. 1988. Pattern and process in arid-region salt marshes--southern California. Pp. 570-581 in D. Hook, W. McKee, Jr., H. Smith, J. Gregory, V. Burrell, Jr., M. DeVoe, R. Sojka, S. Gilbert, R. Banks, L. Stolzy, C. Brooks, T. Matthews, and T. Shear, eds. *Ecology and management of wetlands, Volume 1: Ecology of Wetlands*. Croom Helm, London, U.K.
- Fong, P., C. S. Nordby, J. Covin, J. Tiszler, and J. B. Zedler. 1988. *Goleta Slough Ecological Reserve Management Plan*. Calif. Dept. of Fish and Game, Nongame Heritage Program, Sacramento, Calif.
- Zedler, J. B. 1988. Salt marsh restoration: lessons from California. Pp. 123-138 in J. Cairns, ed. *Rehabilitating damaged ecosystems*. CRC Press, Boca Raton, Fla.
- Zedler, J. B. 1988. Restoring diversity in salt marshes: Can we do it? Pp. 317-325 in E. O. Wilson, ed. *Biodiversity*. National Academy Press, Washington, D.C.
- Zedler, J. B. 1988. Why it's so difficult to replace lost wetland functions. Pp. 121-123 in J. Zelazny and J. S. Feierabend, eds. *Increasing our Wetland Resources*. Conference Proceedings, National Wildlife Federation Corporate Conservation Council, Oct. 4-7, 1987, Washington, D. C.
- Covin, J. D., and J. B. Zedler. 1988. Nitrogen effects on *Spartina foliosa* and *Salicornia virginica* in the salt marsh at Tijuana Estuary, California. *Wetlands* 8:51-65.
- Zedler, J. B., R. Langis, J. Cantilli, M. Zalejko, K. Swift, and S. Rutherford. 1988. Assessing the functions of mitigation marshes in southern California. Pp. 323-330 in J. Kusler, S. Daly,

- and G. Brooks, eds. Urban Wetlands: Proceedings of the National Wetland Symposium, Oakland, California. Assoc. of Wetland Managers, Berne, New York.
- Fong, P., R. Rudnicki, and J. B. Zedler. 1987. Algal community response to nitrogen and phosphorus loadings in experimental mesocosms: recommendations for southern California lagoons. San Diego Association of Governments, San Diego. 102pp.
- Beare, P. A., and J. B. Zedler. 1987. Cattail invasion and persistence in a coastal salt marsh: the role of salinity. *Estuaries* 10:165-170.
- Brenchley-Jackson, J. L., T. C. Foin, and J. B. Zedler. 1987. Modeling the effect of salinity and inundation on *Spartina* and *Salicornia* in southern California. Proc., Wetland and Riparian Ecosystems of the American West. In Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 261-266.
- Fong, P., R. Rudnicki, and J. B. Zedler. 1987. Phytoplankton response to nutrient loadings: a community versus component approach. Proc., Wetland and Riparian Ecosystems of the American West. In Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 61-64.
- Rudnicki, R., P. Fong, and J. B. Zedler. 1987. Macroalgal response to nutrient loadings of varying N:P ratios. Proc., Wetland and Riparian Ecosystems of the American West. In Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 65-67.
- Zedler, J. B., E. Paling, and A. McComb. 1987. Salinity-controlled invasions of *Typha* in Mediterranean-type wetlands of Australia and California. Proc., Wetland and Riparian Ecosystems of the American West. In Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 299-303.
- Griswold, T. J., C. Nordby, and J. B. Zedler. 1987. Simulated salt marshes: methods for reducing experimental error. Proc., Wetland and Riparian Ecosystems of the American West In Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 315-317.
- Wood, L. F., and J. B. Zedler. 1987. Dune vegetation at Tijuana Estuary: interactions between the exotic annual, *Cakile maritima*, and the native perennial, *Abronia maritima*. Proc., Wetland and Riparian Ecosystems of the American West. In Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 322-323.
- Fink, B. H., and J. B. Zedler. 1987. Revegetation of southern California coastal dunes as dictated by stress tolerance studies. In Proc., Wetland and Riparian Ecosystems of the American West. Eighth Ann. Meeting of the Soc. of Wetland Scientists. Pp. 324-326.
- Zedler, J. B., and C. S. Nordby. 1986. The ecology of Tijuana Estuary: an estuarine profile. U.S. Fish Wildl. Serv. Biol. Rep. 85 (7.5). 104pp.
- Zedler, J. B. 1986. Catastrophic flooding and distributional patterns of Pacific cordgrass (*Spartina foliosa* Trin.). *Bull. So. Calif. Acad. Sci.* 85:74-86.
- Zedler, J. B., and P. A. Beare. 1986. Temporal variability of salt marsh vegetation: the role of low-salinity gaps and environmental stress. Pp. 295-306 in D. Wolfe, ed. *Estuarine Variability*. Academic Press.
- Zedler, J. B., J. Covin, C. Nordby, P. Williams, and J. Boland. 1986. Catastrophic events reveal the dynamic nature of salt marsh vegetation. *Estuaries* 9:75-80.
- Zedler, J. B. 1986. Mitigation problems on the southern California coast: an ecologist's view. *WaterfrontAge* 3:32-36.

- Zedler, J. B. 1986. Salt marsh restoration: trials and errors or ecotechnology. Pp. 11-16 in R. Strickland, ed. *Wetland functions, rehabilitation and creation in the Pacific Northwest: the state of our understanding*. Washington State Dept. of Ecology, Olympia, Washington.
- Cox, G. W., and J. B. Zedler. 1986. The influence of mima mounds on vegetation patterns in the Tijuana Estuary salt marsh, San Diego County, Calif. *Bull. So. Calif. Acad. Sci.* 85:158-172.
- Zedler, J. B. 1985. Wastewater input to coastal wetlands: management concerns. Pp. 127-132 in P. Godfrey, E. Kaynor, and S. Pelczarski, eds. *Ecological Considerations in Wetlands Treatment of Municipal Wastewaters*. Van Nostrand Reinhold Co., New York.
- Zedler, J. B. 1985. Salt marsh restoration in southern California. *Restoration and Management Notes* 3:35-36.
- Zedler, J. B., T. Huffman, and M. Josselyn, eds. 1985. Pacific Regional Wetland Functions. Workshop Proceedings. The Environmental Institute, Publication No. 90-3. University of Massachusetts, Amherst. 162 pp.
- Zedler, J. B. 1984. *Salt marsh restoration: a guidebook for southern California*. California Sea Grant College Program. Report No. 7-CSGCP-009. 46pp.
- Zedler, J. B., and C. P. Onuf. 1984. Biological and physical filtering in arid-region estuaries: seasonality, extreme events, and effects of watershed modification. Pp. 415-432 in V. S. Kennedy, ed. *The Estuary as a Filter*. Academic Press, New York.
- Zedler, J. B., and W. P. Magdych. 1984. Sedimentation and estuarine productivity: research priorities for management. Pp. 113-128 in Proceedings of the National Estuarine Research Symposium, March 1984, B. J. Copeland et al., eds. Univ. of North Carolina Sea Grant Program.
- Zedler, J. B., and P. A. Beare. 1984. Mediterranean-type estuaries: resilience to extreme flood events. Pp. 175-176 in Proceedings of the Fourth International Conference on Mediterranean Ecosystems, August 1984, Univ. of Western Australia, Perth.
- Zedler, J. B., and G. W. Cox. 1984. Characterizing wetland boundaries: a Pacific coast example. *Wetlands* 4:43-55.
- Zedler, J. B., R. Koenigs, and W. Magdych. 1984. Freshwater release and southern California coastal wetlands; Report 1, Streamflow for the San Diego and Tijuana Rivers; Report 2, Review of salinity effects and predictions of estuarine responses to lowered salinity; Report 3, Management plan for the beneficial use of treated wastewater in the Tijuana River and San Diego River estuaries. San Diego Assoc. of Governments, San Diego.
- Zedler, J. B., M. Josselyn, and C. P. Onuf. 1983. Restoration techniques, research, and monitoring: vegetation. Pp. 63-72 in Proceedings of the Workshop on Wetland Restoration and Enhancement in California, Feb. 18-20, 1982, Calif. State Univ., Hayward. California Sea Grant College Program, La Jolla, Calif. Report No. T-CSGCP-007.
- Metz, E., and J. B. Zedler. 1983. Who says science can't influence decision making? Proceedings, *Coastal Zone '83*, Vol. I:584-600. Am. Soc. Civil Engr., New York.
- Metz, E., and J. B. Zedler. 1983. Using science for decision making: the Chula Vista Bayfront Local Coastal Program. Salt marsh restoration: the experimental approach. Proceedings, *Coastal Zone '83*, Vol. III:2578-2586. Am. Soc. Civil Engr., New York.
- Zedler, J. B. 1983. Freshwater impacts in normally hypersaline marshes. *Estuaries* 6:346-355.

- Zedler, J. B. 1982. Salt marsh vegetation: examples from the Tijuana Estuary. California Sea Grant College Program, La Jolla, Calif. E-CSGCP-003. 37 pp. (Also translated into Spanish by D. Soto).
- Zedler, J. B. 1982. Salt marsh algal mat composition: spatial and temporal comparisons. *Bull. Southern California Acad. Sci.* 81:41-50.
- Zedler, J. B. 1982. *The ecology of southern California coastal salt marshes: a community profile.* U.S. Fish and Wildlife Service, Biological Services Program, Washington, D. C. FWS/OBS-31/54. 110 pp.
- Zedler, J. B. 1981. The San Diego River marsh before/after the 1980 flood. *Environment Southwest* 495:20-22.
- Zedler, J. B. 1980. Algal mat productivity: comparisons in a salt marsh. *Estuaries* 3:122-131.
- Zedler, J. B., T. P. Winfield, and P. Williams. 1980. Salt marsh productivity with natural and altered tidal circulation. *Oecologia (Berl.)* 44:236-240.
- Emerson, S., and J. B. Zedler. 1978. Recolonization of intertidal algae: an experimental study. *Marine Biology* 44:315-324.
- Zedler, J. B., T. P. Winfield, and D. Mauriello. 1978. Primary productivity in a southern California estuary. Proceedings, *Coastal Zone '78*, Vol. II:649-662. Am. Soc. Civil Engr., New York.
- Zedler, J. B. 1977. Salt marsh community structure in the Tijuana Estuary, Calif. *Estuarine and Coastal Marine Science* 5:39-53.
- Hurlbert, S. H., J. B. Zedler, and D. A. Fairbanks. 1972. Ecosystem structure-alteration by mosquitofish (*Gambusia affinis*) predation. *Science* 175:639-641.
- Zedler, J. B., and O. L. Loucks. 1969. Differential burning response of *Poa pratensis* fields and *Andropogon scoparius* prairies in central Wisconsin. *Amer. Midl. Nat.* 81:341-352.
- Zedler, J. B., and P. H. Zedler. 1969. Association of species and their relationships to microtopography within old fields. *Ecology* 50:432-442.
- Zedler, J. B. 1968. Vegetational response to microtopography on a central Wisconsin drained marsh. Ph.D. Thesis, Univ. of Wisconsin, Madison. 90 pp.
- Zedler J. B. 1966. Buena Vista Marsh in historical perspective. M.S. Thesis, Univ. of Wisconsin, Madison. 75 pp.

Recent reports

- Zedler, Joy B. 2012. Innovationa to improve stormwater treatment. Environmental Protection Agency – Great Lakes Restoration Initiative. Final Report. EPA Region V, Chicago.
- Zedler, Joy B. , and Paul H. Zedler. 2012. Learning while sustaining biodiversity at the Arboretum and beyond; with Appendices by Isabel Rojas Viada. Final report, UW-Madison Morgridge for Service Learning.
- Zedler, J. B., V. Temperton, D. Lamb, R. J. Hobbs, E. S. Higgs, J. A. Harris, Y. D. Choi, and E. B. Allen. 2012. Novel approaches for the novel present and future. Proceedings, 4th International Symposium of the National Institute of Ecology, South Korea: “Importance of Ecological Restoration Studies in the Changing Environment”, October 16 -17, 2012, Seocheon, South Korea.

- Zedler, J. B., Editor. 2012. Eco-Cultural Restoration of the Ho-Nee-Um Pond Landscape at the UW-Madison Arboretum. Botany 670 Class Report. Archived at the Arboretum.
- Zedler, J. B. and the Botany 670 Class. 2010. An Adaptive Restoration Plan for Spring Green's "Prairie View." Town Board, Spring Green, WI.
- Zedler, J. B., J. M. Doherty, and the Botany 670 Class. 2009. An Adaptive Approach to Restoring Culturally-Important Plants at Grand Portage National Monument. Grand Portage National Monument, Minnesota. 76 pages.
- Zedler, J. B. 2008. Testing a Comprehensive Strategy for Replacing Monotypic Reed Canary Grass with a Diversity of Native Wetland Plants. Wisconsin Department of Natural Resources, Wetland Program. Madison, WI. 70 pages.
- Zedler, J. B., Editor. 2008. Restoration of the Arboretum's Eastern Wetlands. Results of Practicum by 8 graduate students, UW-Madison Water Resources Management Program. Madison, WI. 134 p. Available online at <http://uwarboretum.org/research>.
- Ferren, W. R., Jr., J. C. Callaway, J. B. Zedler, and Ballona Wetland Restoration Science Advisory Committee. 2007. Ballona Wetland Restoration Project: Habitat descriptions and candidate ecosystem functions for restoration alternatives at Ballona Wetland.
- Zedler, J. B. 2007. The need for continual, adaptive restoration at Tijuana Estuary. Invited by R. Thom, for Proceedings, Estuarine Research Federation.

Recent book reviews

- Zedler, J. B. 2010. Small is Bountiful: A review of *Tidal Freshwater Wetlands* by A. Barendregt, D. Whigham, and A. Baldwin for *Landscape Ecology* 25:815–817.
- Zedler, J. B. 2010. Review of "Sustaining the World's Wetlands: Setting Policy and Resolving Conflicts." *Quarterly Review of Biology* 496:10.
- Zedler, J. B., D. A. Falk, and D. J. Larkin. 2007. Upstart views of restoration icons – a review of the ESA 2006 Symposium in Memphis, TN. *Ecological Society of America Bulletin* 88:104-112.
- Frieswyk, C. B., M. T. Healy, and J. B. Zedler. 2006. Review of *The World's Largest Wetlands*, a book by L. Fraser and P. Keddy. For *Quarterly Review of Biology* 81:196.
- Zedler, P. H. and J. B. Zedler. 2005. Reality check. A review of *Correction Lines* by Curt Meine. *Conservation Biology* 19:1675-1676.

REPORT OF DR. JOY ZEDLER ON
THE MITIGATION PROPOSAL
FOR THE ST. JOHNS BAYOU/NEW MADRID FLOODWAY PROJECT

Dr. Joy Zedler (January 2006)

The U.S. Army Corps of Engineers has issued a Draft Supplemental Environmental Impact Statement for the St. Johns Bayou/New Madrid Floodway project dated December 9, 2005 (RSEIS2). This project would close a levee gap in the New Madrid Floodway on the lower Mississippi River that allows tens of thousands of acres to flood on a two- or three-year basis. It would also install pumps to drain water out of the floodplain, and install a pump on the closed St. Johns basin to drain water out of it. Today, according to analysis by Dr. Curtis Bohlen, more than 80,000 acres flood on a regular basis, with the precise amount depending on the flood frequency. Under various versions of environmental impact statements for the project, the Corps itself has estimated that roughly 18,000 acres of wetlands within the two-year flood elevation and more than 30,000 acres of wetlands when wetlands at higher elevations are included, would have their backwater flooding from the Mississippi River either eliminated or greatly reduced. My understanding is that under the proposed plan (exclusive of mitigation), only two small sump areas of roughly 2,500 acres combined would remain undrained and therefore still be allowed to flood by Mississippi River backwater.

The RSEIS2 for the project offers four separate, but ultimately similar, mitigation scenarios and states that the final, actual mitigation plan will be left to further decision-making.

The RSEIS2 includes some acres of reforestation and manipulation of other tracts on 6,571 acres. RSEIS2 p. 217. However, many of these acres will generally be above the sump area and will therefore be in areas that are at least substantially drained by the project. Accordingly, the RSEIS2 in Appendix C and at page 104 indicates that many reforestation sites will flood only 5% of the time, and that reforestation sites within the New Madrid Floodway will flood only 6% of the time on average. To mitigate for fish impacts, all of the plans rely primarily on the unnatural extension of flooding on a relatively small number of acres of already existing wetlands.¹ The Corps would do this by artificially extending

¹ The 2002 EIS gave a flood elevation of roughly 290 feet for acres that would meet hydrologic wetland criteria, even for farmed wetlands. All of the sump acres are below 290 feet and therefore would qualify as wetlands according

flooding first on a range from slightly more than 1,000 to 2,800 acres in the sump area of either the New Madrid Floodway, the St. Johns Basin, or some of both. These are the areas behind either the existing levees or levees to be built by the project and that would not be drained by the pumps at least before May 15th each spring. The Corps would extend flooding in these areas by closing gates to trap water behind the levees and keep it from receding into the river from April 1st to May 15th. The Corps proposes to do something similar on 430 to 700 acres of land outside the levees (known as Riley Lake) by constructing a weir to block flow out of the “lake,” which is described as an old oxbow lake, only a small portion of which is flooded year-round. Under three of the four scenarios analyzed for the New Madrid Floodway, artificial ponding would provide 98% or more of the mid-season habitat for fish, and under the fourth scenario, it would provide 93% of that habitat. Table 5.7, RSEIS 2 p. 117.²

In short, under the now proposed EIS, the project would drain more than 75,000 acres of frequently flooded floodplain and eliminate or greatly reduce backwater flooding on thousands of acres of wetlands, and would mitigate primarily by artificially extending flooding (using levees) on something between 2,000 and 3,000 acres.³ All or nearly all of these mitigation sites are already wetlands and flood now under variable conditions that are relatively natural in that they turn on the rise and fall of the Mississippi River. This mitigation result allegedly derives from a so-called Habitat Evaluation Procedure model for fish habitat (HEP model).

to this analysis. Riley Lake is also below 288 feet and according to analysis in the 2005 EIS is part of Donaldson Point, floods even more frequently than the project area and therefore would also qualify as wetland.

² The Corps presents a range of additional mitigation measures that also involve artificially manipulating flooding on other sites to be reforested. For example, one option would reforest 100 acres of cropland and increase flood duration, presumably through levees and pumps, to 31% of the mid-season for fish, while another would create fallow habitat and flood it 95% of the time. RSEIS2 p. 197-98. These possible mitigation options are subject to the same problems with artificial flooding that are set forth in this report.

³ The Corps also proposes some acres of reforestation, but most of these acres would rarely be flooded, RSEIS2 p. 104, so they too are not subject to natural hydrologic variability or any semblance thereof. The apparent exception is land around Big Oak Tree State Park, which now floods but which will be subject to some kind of hydrologic enhancement intended to flood according to relatively natural patterns. This effort affects 1,800 acres, but it is dependent on long-term active management, whose problems I discuss below.

For the reasons described below, the claim that this mitigation fully offsets project impacts on aquatic resources is completely inconsistent with scientific understanding of wetland functioning, wetland replacement, wetland restoration, and mitigation of other aquatic areas, as well as inconsistent with established practice under the Section 404 program.⁴ The claim is so outside the range of reasonable scientific understanding that it cannot be seriously advanced as science-based. It therefore should be disregarded.

My comments draw heavily on a 2001 report by the National Research Council of the National Academy of Sciences, *Compensating for Wetland Losses Under the Clean Water Act*, prepared by a panel that I chaired.⁵ This report has been broadly embraced by the U.S. Army Corps of Engineers, which issued a memorandum to the field in 2003 highlighting key recommendations, reaffirming them, and calling the recommendations of this report either a “basic requirement for mitigation success” or a “guide for mitigation site selection.” U.S. Army Corps of Engineers, Memorandum to the Field on Adaptation of NAS Guidelines (Oct. 29, 2003).

1. Inconsistency with Accepted Understanding of the Importance of Natural Hydrology

Aquatic and wetland ecologists agree that natural hydrologic patterns are critical to the ecological functions of rivers and wetlands. In a report on riparian areas that include floodplains, the National Research Council has called hydrology the “master variable” in driving the ecology of river riparian areas, whose key components include not just broad averages but magnitude of water, frequency, duration, timing and rate of change. National Research Council, *Riparian Areas, Functions and Strategy for Management* (2002).

⁴ I also note that the RSEIS2 attempts to minimize the description of impacts on wetlands. For vegetated wetlands, it only discusses as wetland impacts those that would be directly filled, disregarding the elimination or substantial reduction in flooding of thousands of acres of forested and other vegetated wetlands. For farmed wetlands, it claims that only a few hundred acres count even though the Corps’ own hydrologic analysis indicates thousands of acres of cropped areas meet the 15-day inundation requirement. Under the 1987 wetland manual used by the Corps, this kind of direct hydrologic analysis establishes wetland hydrology.

⁵ This report explicitly addresses wetland mitigation. However, the same scientific principles apply to any mitigation activity required to offset impacts on aquatic ecosystems, including floodplain habitat for fish whether or not they qualify as wetlands. The Clean Water Act Section 404(b)(1) guidelines require that impacts on fish habitat be offset in general, as well as impacts on wetlands.

The focus on preserving and or restoring natural hydrologic patterns reflects humility about the limits of our understanding of the role played by each variable for different ecological functions and hard-taught lessons about how alterations of natural hydrology have often had strong effects that were not well understood. For example, disruption of natural flow patterns, and the timing and amount of wet and dry conditions, of Florida's Everglades are believed to be the root cause of the great declines of its fish and wildlife, and the restoration of these natural patterns of flow is the principal goal of a more than \$8-billion restoration plan authorized by Congress. The disruption of natural hydrology caused by levees is believed to be the root cause of the disappearance of more than a million acres of wetlands in coastal Louisiana and a significant contributor to increased hurricane damages. The Corps has proposed an even more expensive plan to restore natural hydrology to reverse the losses of these wetlands. And while these are two of the most high-profile examples of unintended negative consequences of altering natural hydrological conditions, hundreds of papers on rivers and wetlands have demonstrated adverse ecological consequences from hydrologic alteration for countless other rivers and wetlands. Numerous other papers have demonstrated that efforts to restore wetland and river habitat without restoring natural hydrologic patterns nearly always fail to reproduce key aquatic functions.

For this reason, the report of the National Research Council of the National Academy of Sciences, prepared by the committee that I chaired, strongly emphasized the importance of naturally variable hydrological conditions. One of the major guidelines it set forth for wetland mitigation was as follows:

“Restore or develop naturally variable hydrological conditions. Promote naturally variable hydrology, with emphasis on enabling fluctuations in water flow and level, and duration, and frequency of change, representative of other comparable wetlands in the same landscape setting.” NRC, *Compensating for Wetland Losses Under the Clean Water Act* p. 125 (2001).

The report also stated, “Hydrology is most often cited as the primary driving force influencing wetland development, structure, functioning, and persistence. Proper placement within the landscape of compensatory wetlands to establish hydrological equivalence is necessary for wetland sustainability.” Ibid p. 45. Elsewhere, the report stressed, “Hydrological variability should be incorporated into wetland mitigation design and evaluation. . . . Hydrological functionality should be based on comparisons to reference sites during the same time period.” Ibid p. 45. The reference to “reference sites” is to provide a mechanism for imitating natural hydrology.

The Corps has officially embraced this recommendation in its 2003 Mitigation Memo. This memo states: "Natural hydrology is the most important factor in the development of successful mitigation. Wetlands and other waters are very dynamic, and dependent on natural seasonal and yearly variations that are unlikely to be sustainable in a controlled hydrologic environment." This memo goes on to refer to our recommendation to establish natural hydrology as a "basic requirement."

The Corps' claim for this project that the loss of a vast area of seasonally flooded aquatic habitat could be replaced by unnaturally extended flooding on a small area of already existing wetlands would be an extreme example of what the NRC report recommended against.

Related to the biological importance of natural hydrology is a strong recommendation against the reliance on engineering structures even to establish natural hydrology, let alone to distort it. Our report discussed problems with use of engineering structures to establish hydrology, and stated "natural hydrology should be allowed to become reestablished rather than finessed through active engineering devices to mimic a natural hydroperiod," i.e., naturally variable hydrology. The Corps has accepted this recommendation as well, and writes in its memo regarding adoption of NAS recommendations, "Artificial structures and mechanisms should be used only temporarily. Complex engineering and solely artificial mechanisms to maintain water flow normally will not be acceptable in a mitigation proposal."

Because the Corps' proposed mitigation relies on these kinds of artificial engineering structures, not just for fish but also for waterfowl and shorebirds, this proposed mitigation also violates these established principles.

The importance of preserving or reestablishing natural hydrologic variability is closely related to the importance reflected in landscape position. The NRC report notes that "[l]andscapes have natural patterns that maximize the value and function of individual habitats." The report also encourages the preservation of "large buffers and connectivity to other wetlands," and generally recommends locating mitigation sites in comparable landscape positions and with comparable hydrology as the impact site. NRC Report p. 124. Noting that "slight differences in topography," i.e., elevation, have major impacts on hydrology and resulting plants and animals, the report also calls for providing "appropriately heterogeneous topography." Ibid p. 127. The Corps has endorsed this recommendation as well in the 2003 Mitigation Memo. For example, it writes, "attempting to place mitigation in a dissimilar ecological complex than that of the impact water is expected to result in a wetland/water unlikely to replace the

functions of the wetland/water that was lost.” Memo p. 6. It also emphasizes the need for varied topography Memo p. 8-9.

For this project, the Corps has proposed to create small areas to be managed in uniform ways as replacement for lost functions on an extensive expanse of wetlands and floodplain habitats with varied topography, extensive contiguity and, for much of the land, open hydrologic connectivity. This proposal violates the NRC panel’s recommendations as well.

The rationale for the NRC panel’s recommendations applies fully to the proposed project. The project area, according to the 2002 EIS, supports a wide range of fish, bird and amphibian species. These diverse species will use different kinds of habitats affected heavily by variable flood regimes, are adapted to take advantage of natural flood variability, and will therefore benefit from different aspects of that natural hydrology. Artificial flooding, even if it were to benefit some species, will almost certainly disadvantage others. The levees and water control structures designed to achieve ponding will obviously serve to obstruct fish passage. Extensive flooding over a large number of acres for many days, as occurs today, will also do more to trigger water quality filtration functions than somewhat longer flooding over a very small number of acres. Existing flooding will create a range of microhabitats, and interactions between floodplain and stream networks, that could not be mimicked by extended ponding on a small number of acres. The NRC has recommended the importance of these variations in microhabitat explicitly on floodplains:

"River-floodplain systems have a lateral structure that begins at the main channel and progresses through undefeated and vegetated channel borders and floodplain habitats (backwaters and seasonally flooded vegetation types. Backwaters and large-scale eddies provide refuges from the high velocities and colder winter temperatures of the main channel. Within each of the border and floodplain areas, there are distinct patches, usually determined by small differences in land elevation, that in turn determine the period of inundation (or water depth, in permanently flooded areas) and soil saturation."

National Research Council, Restoration of Aquatic Ecosystems p. 181 (citation omitted). The NRC emphasized the importance of this patchiness, writing that "restoration necessarily involves maintenance or recreation of the original patchiness." p. 183, and emphasizing that floodplain connectivity is critical because "[a]nother way in which the character of rivers is drastically altered is by cutting off interactions with the riparian zone and floodplains." Ibid p. 169.

There is also the real risk of a range of additional unintended adverse environmental consequences. Artificially prolonged flooding could also result in a range of biochemical impacts that are hard to anticipate. In the face of the limitations of our understanding, and the repeated demonstration that alterations to natural hydrologic variability tend to have highly adverse consequences, the accepted understanding is that mitigation and other forms of environmental restoration should focus on reestablishing natural hydrologic variability.

In this matter, the Corps has proposed to do the opposite of these recommendations. It would dramatically reduce or eliminate flooding according to a relatively natural pattern on tens of thousands of acres of wetlands and other valuable floodplain areas, and replace them primarily by artificially manipulating the hydrology on a small number of acres of already existing wetlands. According to established understanding, that mitigation should itself be viewed as harmful, and according to accepted scientific understanding, it cannot offset the impacts of this project.

2. Inappropriate Use of Habitat Models

A related flaw with the Corps analysis is its misuse of its habitat models, which go under the general category of Habitat Evaluation Procedures or HEP. By using these models to quantitatively estimate mitigation acreage requirements for dramatically different kinds of habitat under dramatically different hydrologic conditions, the Corps has used these models beyond any scientifically accepted level.

HEP models attempt to evaluate habitat for animals on the basis of very few criteria. For example, the fish model used by the Corps for this project is based entirely on numbers of average daily flooded acres and the different kinds of vegetation on those acres. In and of itself, it does not factor in such obviously critical factors as extent of contiguous habitat, hydrologic variability, microhabitats, temperature, water velocity, relationships among habitat types, and conditions under extreme flooding or drought. It also ignores the values of habitat diversity for the broad range of species being evaluated.

Because of their simplicity, HEP models have generally come into disrepute, particularly if used for more than one target game species. The HEP models for this report are intended to cover a range of species that in reality have different needs. Thus, when the National Research Council evaluated analytical tools for wetland mitigation, it noted that HEP models have often been used in the past, but did not recommend their continued use. *Compensating for Wetland Losses*, ch. 7. The National Research Council has recommended the use of

assessment techniques that meet eight conditions, few of which are met by HEP models.⁶

However, even if HEP models are to be used, it is broadly understood that they can only be used under conditions that essentially compare very similar habitats in all respects other than those varied by the model. For example, the fish HEP model can be used, if at all, to compare different floodplain habitat values for acres with different vegetation that experience similar patterns of natural hydrologic variability in similar landscape contexts. It cannot be used to compare habitats with very different kinds of hydrology, such as one relatively natural and the other highly managed and artificial. The most obvious reason is that no science went into the development of the model to reflect these important differences, such as those between relatively natural hydrology over an extensive landscape and those in a small area subject to artificial flooding and with barriers to fish access. When HEP models are used in fundamentally different hydrologic or landscape settings, or with very different ranges of other important characteristics, they are no longer science-based.

To illustrate the problem, imagine an accurate model used to assess the number of annual calories needed by adults of different weights and heights. Such a model would not imply that adults would be equally healthy regardless of whether they received those calories through balanced meals or through candy bars. Neither would it imply that adults would be healthy whether they eat these calories in three meals a day or in one meal in a single day.

There is no evidence that the fish HEP model was peer-reviewed. At best, the Corps is attempting to use a habitat model for fish that was developed by comparing sites with comparable hydrology and landscape to evaluate mitigation sites with completely different hydrology and landscape position. Even if the HEP

⁶ Key recommendations include that the assessment technique “includes reliable indicators of the important wetland processes (hydrology, sedimentation and primary production)”; that it “incorporates effects of position in landscape”; that it “assess all recognized functions”; that it is “sensitive to changes in performance over a dynamic range” (such as differences in conditions in both very large and very small floods). *Compensating for Wetland Losses* p. 136-137. None of these conditions is met by the HEP models used by the Corps for this project. The RSEIS2 also provides a separate analysis using a different wetland assessment model, the so-called HGM. But there is no need to address the results of this model, since it assessed only the direct filling of vegetated wetlands, and therefore disregarded the thousands of acres of vegetated wetlands that would be impacted through drainage, and it also assessed only a small number of acres of cropped wetlands.

model has validity when used properly, it lacks scientific validity when used in this manner.

3. Incorrect Understanding of Restoration

Restoring natural hydrology is considered to be a, and perhaps the, critical component of mitigation. But as the above discussion implies, artificial manipulation of one aquatic habitat, even if intended to benefit a particular target species, is not considered proper mitigation either by the National Research Council panel's report or by the Corps memo endorsing the panel's views. Artificial hydrologic manipulation is normally considered an environmental harm because even if, in some circumstances, it might benefit one particular species, it can have a range of adverse effects. The RSEIS 2 states (p. 40) that "[r]estoration usually involves replacing the existing habitat with another habitat that is of greater benefit to the target species." This is not an accurate representation of the field of ecological restoration. Rarely is a single species the target, and even if it were, it would not be considered "restoration" to replace thousands of acres of habitat by making a fraction of that area artificially wetter.

4. Failure to Specify Particular Mitigation Site or Other Attributes of Detailed Mitigation Plan

Virtually all assessments of wetland mitigation, as summarized in *Compensating for Wetland Losses Under the Clean Water Act*, have found that most wetland mitigation projects have shortcomings to differing degrees, in that the target wetland mitigation has not fully replaced the lost wetland area and functions. The reasons for their shortcomings include the fact that compensating for wetland losses is technically very challenging and subject to a range of difficulties for even the most promising projects. Another reason is that the degree of commitment to wetland mitigation sites tends to wane once the underlying project has gone forward. The degree and likelihood of a project achieving its stated objective depends on the characteristics of the proposed mitigation sites.

One of the questions addressed by the panel in *Compensating for Wetland Losses* was whether mitigation projects should therefore be completed prior to authorizing project impacts. The panel rejected this requirement on practical reasons, while noting that this level of certainty is one of the potential benefits of wetland mitigation banks. But the report emphasized the critical importance of providing a detailed mitigation plan before approval of project impacts. NRC Report p. 101.

Review of a specific mitigation site and reasonably detailed restoration plans are critical to any assessment of the likelihood of mitigation compliance and the degree of that compliance. These are not minor details that can be resolved later. Given the challenges facing mitigation, there can be no legitimate determination that mitigation is likely to offset project impacts without this information. The NRC panel also recognized that mitigation ratios i.e., the amount of mitigation, needed to be adjusted to reflect the prospects for achieving compliance. NRC Report p. 150. That too cannot occur properly without detailed advance information about mitigation sites and restoration plans.

In the RSEIS2, the Corps does not propose a specific mitigation plan but instead proposes a range of conceptual options. In effect, the sites and restoration plans remain up to future decision-making. Even the four mitigation scenarios specifically analyzed are only some of the possible mitigation options permitted under the analysis. Moreover, even the scenarios are highly general and fail to specify for the most part specific mitigation sites or to offer detailed mitigation plans about the work to be performed on those sites. This uncertainty would remain until well after the decision to proceed on the project, and even until after heavy investment in project construction. Such levels of details do not support any legitimate judgment about the extent to which mitigation will truly offset project impacts, and it is inconsistent with Corps-recommended practice as represented to the NRC panel.

Attachment C
Comments of the Conservation Organizations

On the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)

St Johns Bayou/New Madrid Floodway Wetland Assessment Probability Survey Design

Introduction

Estimates are needed on the acreage and ecological condition of wetlands in the proposed St Johns Bayou and New Madrid Floodway (SJB/NM) Project area. A probability-based survey design was determined to be the best approach to generate the estimates. The survey design randomly selected a candidate set of sampling points. A subset of those sampling points was assessed using desktop assessment methods and field assessment methods. The overall objective of the assessment was to produce statistically valid estimates within defined confidence limits.

Probability survey designs for natural resources, specifically aquatic resources, were developed by the Environmental Monitoring and Assessment Program (EMAP) of the Environmental Protection Agency's (EPA) Office of Research and Development (ORD). The specific approach is called a Generalized Random Tessellation Stratified (GRTS) survey design. The design requires explicitly defined target populations; allowance for each element in the population having the opportunity to be selected with a known probability, and making the sample selection process explicitly random. These three characteristics, in conjunction with well-defined assessment protocols, ensure that data is collected without bias. EMAP strategies and methods have been developed and tested over the last twenty years. They have proven to be effective, accurate, and replicable. The design approach is widely used in the United States and in other countries for the assessment of natural resources. Details regarding the specific application of the probability design to surface waters resources are described in Paulsen et al. (1991) and Stevens (1994). Computer software for developing spatial survey designs and subsequent statistical analyses is available at: http://www.epa.gov/nheerl/arm/designing/design_intro.htm.

Objectives

The objective of the design is to report the amount of wetland acreage and its ecological condition in four project zones.

- (1) St Johns Bayou "5-Year Flood Zone"
- (2) New Madrid Floodway "5-Year Flood Zone"
- (3) St Johns Bayou "Above 5-Year Flood Zone"
- (4) New Madrid Floodway "Above 5-Year Flood Zone."

Wetland ecological condition is reported for:

- (1) "Natural vegetated wetlands," and
- (2) "Farmed wetlands."

For this assessment "farmed wetlands" are defined as "areas that occur in agricultural fields, and meet two (hydrology and hydric soils) or three (hydrology, hydric soils, and hydrophitic vegetation) of the wetland delineation parameters as defined by the Regional Supplement to the U.S Army Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region (2010), and the U.S. Army Corps of Engineers Wetlands Delineation Manual (1987).

This definition was used to distinguish the difference between what could be assessed in the field during a single site visit and the more explicit USDA definition of farmed wetlands. No determination was made about whether a site was prior converted cropland, or considered to be a farmed wetland under relevant Farm Bill regulations.

Design

A two-phase survey design was used to conduct the SJB/NM wetland assessment. The survey design differs slightly between the “Five-Year Flood Zone” and the “Above 5-Year Flood Zone” parts of the St John Bayou and the New Madrid Floodway basins.

Five-Year Flood Zone Design

Phase 1 of the design led to the selection of 300 sample sites located across the “5-Year Flood Zone” part of the St Johns Bayou and the “5-Year Flood Zone” part of the New Madrid Floodway. The 5-Year Flood Zone was demarcated within each basin based on elevation. The Corps of Engineers project team determined the 5-Year Flood Zone for the New Madrid basin as 297 ft elevation and for the St Johns Bayou basin as 296 ft elevation. For purposes of this survey design, the remaining project area at elevations above the “5-Year Flood Zone” is called the “Above 5-Year Flood Zone.”

The 300 Phase 1 sample points were allocated in a stratified manner across the St Johns Bayou 5-Year Flood Zone and New Madrid Floodway 5-Year Flood Zone. The sample points also were stratified within each zone using five aggregated National Land Cover Database (NLCD) categories. Sample points were allocated to the following land cover categories: Cropland, Wetlands, Natural Land, Open Water and Developed. Thirty points were selected for each land cover category in the St Johns Bayou “5-Year Flood Zone” and 30 points were selected for each land cover category in the New Madrid Floodway “5-Year Flood Zone” for a total of 300 points. Accuracy assessments of NLCD were considered during the reporting of assessment results (e.g., see: <http://landcover.usgs.gov/accuracy/>). The stratified survey design ensures that estimates for the two 5-Year Flood Zones have the same margins of error and that all land cover categories are represented in the sample. The first phase sampling provided a sufficient number of natural vegetated wetland and farmed wetland sites on which wetland condition assessments were made.

A “desktop” wetland determination was made for each of the 300 sample sites (See Table 1). The desktop method is described in a separate document. One of four determinations was made: (1) natural vegetated wetland, (2) farmed wetland, (3) non-wetland, and (4) unknown.

Basin/Determinations	Nat. Veg. Wetland	Farmed Wetland	Not Wetland	Unknown
New Madrid	65	35	42	6
St Johns Bayou	68	19	50	13

Table 1: Number of desktop assessment sites in “5-Year Flood Zone” of SJB/NM basins.

Phase 1 of the assessment was not intended to provide an estimate of wetland acreage. Rather, information from the 300 sites was analyzed along with field data collected in the Phase 2 survey (see below). The field data was used to make corrections to the results of desktop assessments completed on the 300 sites. The two sets of information were used to produce a final estimate of wetland acreage. The two-phase procedure generated a lower margin of error for acreage

estimates than if only a field assessment was conducted. Li et al (1992) describe the two-phase statistical estimation procedure and Genet and Olsen (2008) provide an example application to wetlands in Minnesota.

Phase 2 of the survey design is a subsample of candidate field sites that were selected from the 300 sites of from Phase 1. The design also was stratified within each of the zones by three type areas: “Unknown,” “Natural Vegetated Wetlands” and “Farmed Wetlands.” Sites classified as Non-Wetlands in the desktop evaluation were assumed to be correctly classified.

Accurate reporting of wetland condition by wetland type required a minimum sampling of 15 sites of natural vegetated wetlands and 15 sites of farmed wetlands in each zone. While the desktop assessment was intended to aid selection of those sites, some field-checked sites were not determined to be wetlands and some sites could not be accessed because of lack of landowner permission. The Phase 2 sample draw continued until a sufficient number of field sites became available to sample. At the end of the sample draw process, 97 field sites were located in the “5-Year Flood Zones” of the St Johns Bayou and the New Madrid Floodway basins (See Table 2). A field assessment was completed for each of the 97 selected sample points.

Basin/Determinations	Nat. Veg. Wetlands	Farmed Wetlands	Not Wetland
New Madrid	15	15	20
St. Johns Bayou	19	15	13

Table 2. Number of field assessment sites in “5-Year Flood Zone” of SJB/NM basins.

The field assessment of the 97 sites in the “5-Year Flood Zone” accomplished two things. First, it confirmed the desktop wetland determination. For example, field staff confirmed whether a correct desktop determination had been made about a site being a natural vegetated wetland, a farmed wetland or non-wetland. Second, field sampling allowed for a field-based assessment of wetland condition.

“Above 5-Year Flood Zone” Design

The Above 5-Year Flood Zone design is a single phase design. There was no Phase 2 field sampling. The design called for the selection of “desktop” sample sites located across the “Above 5-Year Flood Zone” parts of the St Johns Bayou and the New Madrid Floodway. Sample points were allocated to the following NLCD categories: “Cropland,” “Wetlands,” and “Natural Land.” For purposes of this design, NLCD categories of “Open Water” and “Developed” were assumed to be accurate. No points were allocated to those two categories. This assumption allowed for a reduction in the level of effort for the assessment. The assumption was checked using survey data and assessment results from the 5-Year Flood Zone parts of the project.

Initially, twenty points were selected for each of the three NLCD categories in the St Johns Bayou “Above 5-Year Flood Zone” and 20 points were selected for each category in the New Madrid Floodway “Above 5-Year Flood Zone” for a total of 120 points. Additional “overdraw” sample points were then added to ensure the availability of a sufficient number of sites to report the condition of natural vegetated wetlands and farmed wetlands in each of the “Above 5-Year Flood Zones”.

One of four determinations was made using the “desktop” methodology for the 177 generated sample sites: (1) Natural vegetated wetland, (2) farmed wetland, (3) non-wetland, and (4) unknown. Also, a “desktop” wetland condition assessment was conducted for each sample site that was determined to be a natural vegetated wetland or a farmed wetland.

Basin/Determinations	Natural Veg. Wetland	Farmed Wetland	Unknown	Not Wetland
New Madrid	17	15	3	49
St Johns Bayou	16	17	3	57

Table 3. Number of “desktop” determinations made in “Above 5-Year_Flood Zone” of SJB/NM basins. A desktop condition assessment was completed on each natural vegetated wetland and farmed wetland.

Survey Results For Wetland Acreage

	Both Basins	St Johns Bayou	New Madrid Floodway
Total Wetland	149,802	97,471	49,997
Naturally Vegetated Wetland	31,709	21,540	9,206
"Farmed Wetland"	118,093	75,931	40,791

Table 4. SJB/NM Basins (Both Flood Zones)

	Both Basins	St Johns Bayou	New Madrid Floodway
Total Wetland	63,397	27,420	33,643
Naturally Vegetated Wetland	14,614	5,767	7,884
"Farmed Wetland"	42,985	16,191	25,759
Rice Fields that meet at least hydrology and soil indicators	5,798	5,462	N/A

Table 5. 5-Year Flood Zone

	Both Basins	St Johns Bayou	New Madrid Floodway
Total Wetland	86,405	70,051	16,354
Naturally Vegetated Wetland	17,095	15,773	1,322
"Farmed Wetland"	69,310	54,278	15,032

Table 6. Above 5-Year Flood Zone

The results of the SJB/NM Wetlands Assessment are presented in a set of summary tables. Tables 4, 5 and 6 present acreage estimates for wetlands occurring in the different parts of the basins. Each acreage estimate has an associated statistical confidence interval and confidence limit. For example, the acreage estimate for natural vegetated wetlands located in the 5-Year Flood Zones” of the basins is 14,614 acres. The confidence interval for this value is approximately +/- 5,000 acres. The confidence limit is 90%. From a statistical perspective, if the wetland assessment was conducted over and over again, then 90% of the time the resulting

value would be between 9,614 and 19,614. From a practical perspective, the 14,614 acre value is considered the “best estimate” because it is the value most likely to be produced in a repeated assessment. Likewise, multiple repeated assessments would likely generate a mean value very close to the 14,614 acres. Work on analyzing the condition estimates is still in progress.

References

- Genet, J. A., and Olsen, A. R. (2008), "Assessing Depressional Wetland Quantity and Quality Using a Probabilistic Sampling Design of in the Redwood River Watershed, Minnesota, USA," *Wetlands*, 28, 324–335.
- Li, H. G., Schreuder, H. T., VanHooser, D., and Brink, G. E. (1992), "Estimating Strata Means in Double Sampling with Corrections Based on Second-Phase Sampling," *Biometrics*, 48, 189-199.
- Paulsen, S.G., D.P. Larsen, P.R. Kaufmann, T.R. Whittier, J.R. Baker, D. Peck, J. McGue, R.M. Hughes, D. McMullen, D. Stevens, J.L. Stoddard, J. Lazorchak, W. Kinney, A.R. Selle, and R. Hjort. 1991. EMAP - surface waters monitoring and research strategy, fiscal year 1991. EPA-600-3-91-002. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. and Environmental Research Laboratory, Corvallis, Oregon
- Stevens, D. L., Jr., 1994. Implementation of a National Monitoring Program. *Journal Environ. Management* 42:1-29
- U.S. Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual. Technical Report Y-87-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.
- U.S. Army Corps of Engineers. 2010. Regional Supplement to the Corps of Engineers Wetlands Delineation Manual: Atlantic and Gulf Coastal Plain Region (Version 2.0), ed. J. S. Wakeley, R. W. Lichvar, and C. V. Noble. ERDC/EL TR-10-20. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Jason Daniels/R7/USEPA/US

10/21/2011 03:19 PM

To Brad Horchem, Vicky Johnson

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bcc

Subject SJNM Wetland Assessment Report version as of Oct 21, 2011

Brad and Vicky,

Here is the SJNM wetland assessment report to date for your review. I think this is far enough along for Vicky to take a turn to look at it or we can send to Joe and Chris as well. There are some areas highlighted and in red text that need extra attention, and there are place holders waiting for the data rerun from Tony. The mitigation section added by Rich needs discussion if we want to include any discussion now or at a later date.



Draft SJB_NMF Wetland Assessment Report October 21 2011.docx

Thanks,
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ST. JOHNS BAYOU AND NEW MADRID FLOODWAY (SJB/NMF) WETLAND ASSESSMENT

Introduction

In December 2009, the U.S. Army Corps of Engineers (“Corps”) Memphis District announced its intention to complete a new Environmental Impact Statement (“EIS”) for the St. Johns Bayou/New Madrid Floodway Civil Works Project. The project area encompasses approximately 426,000 acres, including portions of two drainage basins separated by the Birds Point-New Madrid Setback levee. The EIS will include the previously proposed project alternative of drainage modifications, pumping stations, and closure of the last remaining gap, in Missouri, along the mainstream levee of the Mississippi River. The project is in the Southeast portion of Missouri, the counties encompassed by the project are Scott, Mississippi, and New Madrid Counties.

Figure 1. Map of project area.



A wetland assessment was conducted in the summer of 2010 to generate estimates of wetland acreage and wetland ecological condition in the Project area. The wetland assessment was conducted as a collaborative effort involving the Corps and the U.S. Environmental Protection Agency (“EPA”), Region 7 and EPA’s Office of Research and Development. This report describes the design of that assessment and

its results. A short discussion also is presented describing how the information can be used to inform a determination of compensatory mitigation needs associated with the Project.

Information from the SJB/NMF Wetland Assessment is being used in the preparation of the EIS and to inform EPA Region 7's comments on the EIS.

Assessment Objective

The objective of the SJB/NMF Wetland Assessment was to report the amount of wetland acreage and its ecological condition in SJB/NMF Project Area. The area is divided into four zones.

- (1) SJB "Five-Year Flood Zone"
- (2) NMF "Five-Year Flood Zone"
- (3) SJB "Non-Flood Zone"
- (4) NMF "Non-Flood Zone"

Each zone represents a project watershed area demarcated within a broader drainage basin and that area's Five-Year flood recurrence interval with the Mississippi River. The "Five-Year Flood Zones" are demarcated based on elevation. For purpose of this study using information provided by the Corps of Engineers project team, the SJB Five-Year Flood zone is defined as 296 foot elevation. The NMF Five-Year Flood Zone is defined as 297 foot elevation. For purposes of the survey design, the remaining zones outside of the "Five-Year Flood Zone" are called the "Non-Flood Zone." The Corps has recently provided more exact elevations for the Five-Year Flood Zone of 296.6 for the NMF and 294.1 for the SJB.

Wetland ecological condition is reported for:

- (1) "Natural Vegetated Wetlands," and
- (2) "agricultural lands*".

For this assessment, "agricultural lands*" are defined as "areas that occur in agricultural fields, and meet two (hydrology and hydric soils) or three (hydrology, hydric soils, and hydrophytic vegetation) of the wetland delineation parameters as defined by the Regional Supplement to the U.S Army Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region (2010), and the U.S. Army Corps of Engineers wetlands delineation manual (1987). This definition was used to distinguish the difference between the type of wetland determination that could be made in the field during a single site visit and the more explicit USDA definition of farmed wetlands. Due to privacy considerations of landowners, a determination was not made about whether a site was prior converted cropland, or whether an assessed site is considered to be a farmed wetland under relevant Farm Bill regulations. In previous EPA correspondence on acreage results "agricultural lands*" was called "farmed wetlands" but shares the same definition as above.

Survey Design

A probability-based survey design was used to generate estimates of wetland acreage abundance and condition in the SJB/NMF Project Area. This type of survey was needed because accurate maps of wetland occurrence in the project area are not available.

Probability survey designs for natural resources, specifically aquatic resources, were developed by the Environmental Monitoring and Assessment Program (EMAP) of the Environmental Protection Agency's (EPA) Office of Research and Development (ORD). The specific approach is called a Generalized Random Tessellation Stratified (GRTS) survey design. The design requires explicitly defined target populations; allowance for each element in the population having the opportunity to be selected with a known probability; and making the sample selection process explicitly random. These three characteristics, in conjunction with well-defined assessment methods, ensure that data is collected without bias. EMAP strategies and methods have been developed and tested over the last twenty years. They have proven to be effective, accurate, replicable, and readily available. The design approach is widely used in the United States and in other countries for the assessment of natural resources. Details regarding the specific application of the probability design to surface waters resources are described in Paulsen et al. (1991) and Stevens (1994). Computer software for developing spatial survey designs and subsequent statistical analyses is available at: http://www.epa.gov/nheerl/arm/designing/design_intro.htm.

Both a single phase and a two-phase (or double sample) GRTS survey design were used in the SJB/NMF Wetland Assessment to address cost and level-of-effort constraints on the number of sample sites that could be assessed. Each phase of the design is described in the following sections of this report.

Design for SJB Five-Year Flood Zone and NMF Five-Year Flood Zone

A two-phase estimation approach was used to generate the survey design for SJB Five-Year Flood Zone and NMF Five-Year Flood Zone. The two-phase design was structured to first provide an estimate of wetland abundance (acreage) in the each zone, and then to statistically target a subset of wetland area for an assessment of wetland condition.

The two-phase procedure has the advantage of generating a lower margin of error for acreage estimates than if only a field assessment was conducted. Li et al (1992) describe the two-phase statistical estimation procedure and Genet and Olsen (2008) provide an example application to wetland assessment in Minnesota. The procedure is based on the premise that a first phase, "desktop," wetland determination made for a sample site is subject to potential misclassification. The second phase, "field," wetland determination is taken to be the correct classification. The information from the second phase is used to statistically correct for the misclassifications that occur in the first phase. For the estimation process, field determinations were not used to change desktop classifications, and field determinations were not changed to match desktop determinations. Rather, the statistical correction is based on the classification error rates observed between the two phases. A description of the "desktop" and "field" assessment methods are described later in this report.

Phase 1 of the design led to the selection of 300 sample sites located across the combined SJB and NMF Five-Year Flood Zones. The sample points were stratified within each zone using five aggregated National Land Cover Database (NLCD) categories. Sample points were allocated to the following land cover categories: Cropland, Wetlands, Natural Land, Open Water and Development. A land cover category was assigned to each selected point. Thirty (30) points were selected for each land cover category in the SJB Five-Year Flood Zone and thirty points were selected for each land cover in the NMF Five-Year Flood Zone ($30 \times 5 + 30 \times 5 = 300$ sites). Accuracy assessments of NLCD were considered during the reporting of assessment results (e.g., see: <http://landcover.usgs.gov/accuracy/>). The stratified survey design ensured that estimates for the two flood zones have the same margins of error and that all land cover classes are represented in the sample.

A “desk-top” wetland determination was made for each of the 300 sample sites (**See Table 1**). The desk-top method is described in the next section of this report. Using the method, a wetland determination produced one of four determinations: (1) natural vegetated wetland, (2) “agricultural lands*”, (3) non-wetland, and (4) unknown.

Table 1. Number of desk-top assessment sites in the SJB Five-Year Flood Zone and the NMF Five Year Flood zone.

Basin/Determinations	Nat. Veg. Wetland	“Agricultural Lands*”	Not Wetland	Unknown
New Madrid Floodway	65	35	44	6
St. Johns Bayou	68	19	51	12

Phase 2 of the survey design is a subsample of candidate field sites that were selected from the 300 sites of the Phase 1 sample. The Phase 2 design was stratified by the SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone. The design also was stratified within each of the zones by three type areas: “Unknown,” “Natural Vegetated Wetlands” and “agricultural lands*.” Sites classified as Non-Wetlands in the desktop evaluation were assumed to be correctly classified.

Accurate reporting of wetland condition by wetland type required that a minimum field sampling of 15 sites of Natural Vegetated Wetlands and 15 sites of “agricultural lands*” in each of the SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone. While the desk-top assessment was intended to aid selection of those sites, some field-checked sites were not determined to be wetlands and some sites could not be accessed because of lack of land owner permission. The Phase 2 sample draw continued until a sufficient number of field sites became available to sample. At the end of the sample draw process, 97 field sites were located in the combined SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone (See **Table 2**).

Table 2. Wetland determinations made by field assessment in the SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone.

Basin/Determinations	Natural Vegetated Wetlands	“Agricultural Lands*”	Not Wetland
New Madrid Floodway	13	15	22
St. Johns Bayou	18	15	14

A field assessment was completed on each of the 97 selected sample points. The field assessment of the sites accomplished two things. First, it assessed the accuracy of the desk-top wetland determination. For example, field staff confirmed whether a correct desk-top determination had been made about a site being a Natural Vegetated Wetland, a “agricultural lands*” or non-wetland. Second, field sampling allowed for a field-based assessment of wetland condition.

Design for SJB Non-Flood Zone and NMF Non-Flood Zone

A single phase survey design was applied to the SJB Non-Flood Zone and NMF Non-Flood Zone. There was no Phase 2 field sampling because of cost and level-of-effort constraints. The design called for the selection of sample sites located across the non-flood zones. Those sites would be assessed using “desktop” assessment methods used in an office setting. Sample points were allocated to the following NLCD categories: “Cropland,” “Wetlands,” and “Natural Land.” For purposes of this design, NLCD categories of “Open Water” and “Development” were assumed to be accurate. No points were allocated to those two categories. This assumption allowed for a reduction in the level of effort for the assessment. The assumption was checked using survey data and assessment results from the SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone.

Initially, twenty (20) points were selected for each of the three NLCD categories in the SJB Non-Flood Zone and 20 points were selected for each category in the NMF Non-Flood Zone ($20 \times 3 + 20 \times 3 = 120$). Additional “overdraw” sample points were then added to ensure the availability of a sufficient number of sites to report the condition of Natural Vegetated Wetlands and “agricultural lands*” in each of the non-flood zones.

A “desk-top” wetland determination was made for the 177 generated sample sites. A wetland determination produced one of four determinations: (1) natural vegetated wetland, (2) “agricultural lands*”, (3) non-wetland, or (4) unknown. Also, a “desk-top” wetland condition assessment was conducted for each sample site that was determined to be a natural vegetated wetland or “agricultural lands*” (See **Table 3**).

Table 3. Number of desktop determinations made in the SJB Non-Flood Zone and the NMF Non-Flood Zone. A desk-top condition assessment was completed on each Natural Vegetated Wetland and “agricultural lands*.”

Basin/Determinations	Natural Vegetated Wetland	“Agricultural Lands*”	Unknown	Not Wetland
New Madrid Floodway	17	15	3	49
St. Johns Bayou	16	17	3	57

Wetland Assessment Methods

The sample points selected by the above-described survey design were assessed using desktop and field methods. One set of methods were developed for making wetland determinations and another set of methods were developed to assess wetland condition. “Desktop” methods were applied in an office setting using mapped information and aerial photography. “Field methods” were applied by agency staff at survey sample points accessed in the project area.

Desktop method for wetland determination

A “desktop” wetland determination was made for each of the 477 sample sites identified by the survey design described in the previous section of this report. Three hundred (300) sample sites were selected across the SJB Five-Year Flood Zone and NMF Five Year Flood Zone. One hundred and seventy-seven (177) sample sites were selected across the SJB Non-Flood Zone and the NMF Non-Flood Zone. The desktop wetland determinations were based on two factors.

The first factor is whether the sample site is located in an area designated as wetland on existing National Wetland Inventory maps, and/or located in an area mapped as having hydric soils or soils with hydric inclusion. The second factor is whether the sample point appeared as a wetland on aerial imagery based on use of a selected set of indicators (i.e., wetland signatures). The indicators are described by the Minnesota Board of Water and Soil Resources (MN BWSR, 2010) and the Natural Resources Conservation Service’s Missouri Wetland Mapping Convention (NRCS, 1995).

The indicators are:

1. Crop stress. Differences observed in vegetation vigor of planted crops as compared to surrounding conditions due to wetness.
2. Drowned-out vegetation. Observed cropped areas appear to have been tilled through and planted, but all or part of the crop has been drowned-out.
3. Standing water or wet soils. Surface water is visible. In infrared imagery, standing water is lead colored and stands out fairly well. Moist soil with standing water is a different hue (lighter in base) than adjacent vegetation in wetland conditions. Wetland signatures in freshly disked prior-converted cropland and farmed wetland fields are darker in hue than non-wet areas.
4. Altered Cropping Pattern. Observed differences in vegetation or cropping patterns resulting from delayed planting dates or other alterations to standard farming practices as a result of wetness.
5. Drainage Swale. Observed landform feature caused by the unidirectional flow of water, and/or water marks, drift lines, or sediment deposits are visible.
6. Not Cropped. Area appears to have natural vegetation cover rather than annual crops or is bare. Adjacent cropped area is squared-up or otherwise planted in a pattern that avoids the area.
7. Wetland Signature. Natural vegetation is observed in a non-cropped area.

The imagery used to make a desktop wetland determination was selected to represent a dry year (2010), wet years (2003, 2007 and 2009) and years of average precipitation (2004, 2005 and 2006). Information used to classify wet and dry years was obtained from Kevin Dacey (personal communication, 2010). Imagery consisted of:

IR – Infrared Aerial Photography

NAIP – National Agriculture Imagery Program

MO – Missouri 2-Foot Resolution Aerial Photography (<http://msdis.missouri.edu/data/2foot/index.htm>)

a. 2003 IR	d. 2006 NAIP	g. 2009 NAIP
b. 2004 NAIP	e. 2007 NAIP	h. 2009 IR
c. 2005 NAIP	f. 2007 MO	i. 2010 NAIP

The aerial images were rectified to the SJB/NMF Project Area using EPA Region 7's Geographical Information System (GIS). In addition, the following spatial data layers were entered into the GIS.

- a. National Land Cover Data Set (NLCD)
- b. National Wetland Inventory (NWI) (*need date*)
- c. Hydric soils and soils with hydric inclusions.

The desktop assessment of wetland occurrence was completed by interagency teams. Each determination was based on the consensus opinion of the assessment team. Results were entered into a spreadsheet. The following specific procedures were used to make a determination.

1. Confirm Land Use Class. Using aerial interpretation, each sample point was examined to ensure that it was located within the land cover class specified by the survey design. This task was a quality control check on the number of sample points allocated by the survey design to each of the five categories of NLCD land cover classes: cropland, developed land, open water, wetlands, and natural land.

If a sample point was located in a developed area, then the most recent aerial imagery was used to confirm the presence of buildings, roads or other developed land features. If the sample point was confirmed within a developed area, then the status of the site was recorded as "Not a Wetland." If the sample point was within an undeveloped area, then additional steps in the assessment procedure were completed.

2. Conduct Assessment. Each sample site that was located in an undeveloped area was assessed using the above specified indicators, the described imagery, NWI maps and soils information. Each assessment began by looking at aerial imagery that reflected the most recent wet year. During the assessment each indicator was scored as either being present or absent. **Table 4** was used to guide the wetland determination procedure.

Table 4 – Factors used to make a "desktop" wetland determination.

Wetland Determination Factors		
Number of mapped indicators (NWI and Soils)	Number of indicators (wetland signatures) observed on aerial photos	Determination
2	≥2	Wetland
1	≥3	Wetland
0	≥3 with at least one non-wet year	Wetland
2	≤1	Unknown
1	1 or 2	Unknown
0	2	Unknown
1	0	Not a Wetland

0	≤1	Not a Wetland

For example, if a sample site is located in an area mapped as a wetland by NWI, and “crop stress” was observed in aerial imagery representing three different years, then the site was determined to be a “Wetland.” In contrast, if a sample site is located in an area mapped as having hydric soils, but metrics (signatures) are not observed on the site based on review of multiple years of imagery, then the site was determined to be “Not a Wetland.” A determination of “Unknown” was made in those situations where there was relatively weak indication of either presence or absence of a wetland, and/or when the assessment team could not reach group consensus.

3. Determine Wetland Type. A wetland type was assigned to each sample site that was determined to be a wetland. The site was classified as either being a “Natural Vegetated Wetland or a “agricultural lands*.” The decision was based on observations of the most recent aerial imagery and use of the indicators described above. Observation of “Crop Stress”, “Drowned-out Vegetation”, or “Altered Cropping Pattern” indicated the area is a “agricultural lands*.” Findings of “Not Cropped” or “Wetland Signature” indicated the site was not an “agricultural lands*.”

4. Training and Quality Assurance

Training for this desktop method consisted of a training by a National EPA expert on photo interpretation and group discussion about the indicators, aerial imagery and factors used to make a wetland determination. Several “practice” assessments were conducted by all team members using survey sample points. Results from that exercise were reviewed and reconciled in a group setting. Whenever a team member found something on an aerial photo that they were not sure of the entire group was consulted and consensus was achieved. All unknown or difficult points were reviewed by the entire group. Quality assurance was achieved based on the method requiring full consensus to make a determination.

Field method for wetland determination

Ninety seven (97) survey sample sites were visited within the combined SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone. Each survey sample site was visited by a team of two or more individuals trained in the use of the U.S. Army Corps of Engineers, 2008, Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region (Corps of Engineers, 2008) and the Corps of Engineers 1987 Wetland Delineation Manual (Corps of Engineers, 1987). Three teams conducted field work and were made up of at least one individual representing the Corps and one individual representing the EPA. Consensus of the field data for delineation indicators occurred before leaving each site. Using the specifications described in the manuals, each team made a field determination on whether the site was a:

- a. Natural Vegetated Wetland,
- b. “agricultural lands*,” or
- c. Not a Wetland

At the end of each field day, wetland determination forms were reviewed to ensure that field forms were fully completed. If any questions came up during the day they were shared among all team members present. If consensus on how to document any question could not be reached, Corps staff

contacted ERDC delineation experts for additional support and reported the information back to the teams. For any plants that could not be identified in the field a sample was collected and brought back to be reviewed by the greater team, eventually all plants were identified. The majority of point's data forms were finalized the day of sampling. EPA provided all the data forms to a consultant to enter the data. The consultant developed a spreadsheet with all the field data and identified areas that were difficult to read, blank, or unclear. EPA went through each of the identified areas and provided up dated information, and added notes to the data sheets. During this process additional quality assurance checks were made to assure that the correct conclusions were made. Some of the fields on the data forms were left blank, such as location data, however they can be cross referenced geospatially with GIS by each point's number.

There were some points where additional review was conducted post field work. Determinations that were made at survey sample points and that were documented as having hydric soils, wetland vegetation, and met one of two secondary hydrology indicators. The additional review was conducted using the aerial imagery described in the previous section of this report. In three instances (points 1007, 1060, and 1100 the field-based determination was changed to take into account the hydrological information provided by the aerial imagery necessary to meet the C9 hydrology indicator and thus give these points two secondary indicators. The procedure of using aerial imagery to inform a field-based wetland determination is explained in the referenced wetland delineation manuals. The Corps of Engineers requested that these sample points be changed back to non-wetland. The results in this report represent values with these three points as non-wetland, see previous documents for estimates based on these three points as wetland.

Overview of wetland condition assessment and the "index of wetland condition (IWC)"

Both a desktop method and the field method were developed to assess wetland condition. Each method relies on the use of an index of wetland condition ("IWC"). The IWC is a multi-metric measure consisting of wetland variables that reflect the ecological condition of a wetland assessment area. Ecological condition means the ability of a wetland to support and maintain its complexity and capacity for self-organization with respect to species composition, physio-chemical characteristics, and functional processes as compared to wetlands of a similar type without human alterations. Ecological condition results from the integration of the chemical, physical and biological functions that maintain the system over time. (Fennessy et al, 2007). In simplest terms, condition reflects the health of a wetland.

The development of the IWC assessment methods generally followed the approach described by Jacobs et al. (2010). The wetland assessment variables used in the IWC methods were selected from the *"Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the Delta Region of Arkansas"* (Klimas et al. 2009). The initial selection was based on their perceived applicability to rapid field assessment and to the interpretation of aerial imagery and maps. Two other variables were selected based on reference site data used in the development of the Regional Guidebook. The selection of all variables was performed by staff from the U.S. Army Corps of Engineers Engineer and Development Center (ERDC) in collaboration with EPA staff in EPA Region 7.

Scaling curves for the individual IWC variables is documented in the Regional Guidebook. Scaling curves correspond to each of the major hydrogeomorphological (HGM) types of wetland in the SJB/NMF Project Area: Riverine Backwater Wetland, Riverine Overbank Wetland, Depressional Wetland and Flats Wetland. Each scaling curve depicts the range of IWC attribute values expected to occur along a gradient of human-caused wetland disturbance. Curves were generated from a set of reference sites

selected, in the past and apart from the SJB/NMF Wetland Assessment, to represent the disturbance gradient. The reference sites are those that were used to develop the Regional Guidebook.

For most of the IWC variables, the scaling curves were used to assign a variable score to each variable in the desktop method and the field method. The scores ranged from 0.1 to 1.0. To generate an overall IWC score, individual variable scores for an assessment area were averaged, and then were multiplied by 100.

A new scaling curve was generated for one of the IWC variables used in the wetland assessment. The scaling curve for the “Canopy Tree Density (V_{CTDEN})” variable was generated after analysis of the field data collected for the “Tree Density (V_{TDEN})” variable. The new scaling curve was made by multiplying the values in the V_{TDEN} curve by 0.6. That coefficient is used to correlate the new V_{CDEN} scoring curve, as applied in the IWC Desktop method, to the V_{TDEN} variable scores generated by the IWC Field method. In other words, V_{CDEN} is scaled to reflect the range of conditions measured in the SJB/NMF Project Area. The coefficient is based on the removal of data outliers observed in the V_{TDEN} field sampling data set. This was done in collaboration between EPA and ERDC.

The data reporting forms for the “IWC-Field Method” and the “IWC-Desktop Method” each had a place for recording the HGM type of wetland being assessed. The following guidance was provided to assessment teams along with a classification key.

In general, the most prevalent subclass within the Five-year Flood Zone parts of the SJB/NMF Project Area are “riverine backwater” type wetlands, with connected “depressional” wetlands occurring in topographic lows, and “riverine overbank” wetlands generally limited to the riverbanks where natural levee deposits occur, and evidence of high-energy flows is apparent. In the Non-Flood Zone Parts of the Project Area “flats” type wetlands is the most common subclass, with unconnected depressions occurring in topographic lows.

Also, the data reporting forms for the IWC-Field Method and the IWC-Desktop Method each had a place for recording the type of geomorphic surface that the sample site is located. The age and origin of the geomorphic surface influences the amount of microtopographic relief naturally present in reference standard sites; with older surfaces having less relief. Thus, there are different scaling curves for the ponding variable in Flats for different geomorphic surfaces. Within the project area, there are only two types of surfaces: Pleistocene Valley Train Terraces and Holocene Alluvium. The site locations were compared to the digital version of Saucier’s 1994 geomorphology map (Saucier, 1994) in a Geographic Information System (GIS) program to make this determination.

The variables selected for the IWCs are described in the following sections and in Appendix A of this report. The initial scaling and scoring of the variables was based on “scaling curves” presented in the above-cited Regional Guidebook and presented in Appendix B of this report. The final selection of IWC variables and the final scaling of the overall IWCs for reporting wetland condition took into consideration data collected in the SJB-Five Year Flood Zone and the NMF Five-Year Flood Zone using the IWC-Field Method. Further discussion of the process used to review the scaling of variables is presented in the results section of this report.

IWC-Field Method

Table 5 lists the wetland condition variables used in the IWC-Field Method. The variables are described in Attachment A. The variables are grouped by “wetland attribute” (i.e., landscape character, hydrology and vegetation). The method initially included a variable used to measure soil integrity (“ V_{SOIL} ”). The variable was removed from the method during the field assessment because field teams experienced difficulty in agreeing on the definition of the variable and how it should be measured.

The IWC-Field Method was applied at sampling points selected by the survey design within the SJB Five-Year Flood Plain and the NMF Five-Year Flood by the survey design. The landscape variables for each sampling point were measured in an office using airphotos and maps. The remaining variables were assessed in the field. For purposes of the field assessment, each sample point was assigned a 0.5 ha assessment area. The assessment area was demarcated as a circular 0.5-ha plot (39.9-m radius, or 131-ft radius). When necessary, the shape of the plot was adjusted to best represent the plant community of the selected survey sample point. Smaller, nested plots within the assessment area were established for measurement of the V_{TDEN} and V_{GVC} variables.

Table 5. Variables used in IWC-Field method to assess wetland condition in SJB/NMF Flood Zone Project Area.

<u>Landscape Variables</u>	<u>Vegetation Variables</u>
V_{TRACT} - Wetland tract	V_{STRATA} - Number of vegetation strata
V_{CORE} - Core area	V_{TDEN} - Tree density
$V_{CONNECT}$ - Connectivity	V_{COMP} - Composition of tallest woody vegetation stratum
<u>Hydrology Variables</u>	V_{GVC} - Ground vegetation cover
V_{POND} - Percent of site subject to ponding (microtopographic relief)	

IWC-Desktop Method

Table 6 lists the wetland assessment variables used in the IWC-Desktop Method. The variables are described in Attachment 1. The method initially included a variable used to measure soil integrity (“ V_{SOIL} ”) and another variable to measure the percentage of the assessment area subject to ponding (“ V_{POND} ”). V_{SOIL} was removed because of difficulty in agreeing on the definition of the variable and how it should be measured. V_{POND} was removed because of difficulty in making a measurement and because of the high natural variability of site conditions as observed from airphotos of different years.

Also, two vegetation variables that are not part of the referenced Regional Guidebook were added to the method. The first is “Top Vegetation Stratum ($V_{TOPSTRATUM}$)” and the second is “Canopy Tree Density (V_{CTDEN}).” The scaling curve for $V_{TOPSTRATUM}$ was derived from reference data sets used to develop the Regional Guidebook. The scaling curve for V_{CTDEN} was discussed above in the overview of wetland condition assessment.

Table 6. Variables included in the IWC-Desktop method

<u>Landscape Variables</u>	<u>Vegetation Variables</u>
V_{TRACT} - Wetland Tract	$V_{TOPSTRATUM}$ - Top Vegetation Stratum
V_{CORE} - Core Area	V_{CTDEN} - Canopy Tree Density
$V_{CONNECT}$ - Connectivity	V_{GVC} - Ground Vegetation Cover

Hydrology Variables
(none)

Assessment Results

The results of the SJB/NM Wetlands Assessment are presented in a two sections. The first section presents estimates of wetland acreage in parts of the SJB/NMF Project Area. The second section presents estimates of the ecological condition of that wetland resource. The second section also includes a discussion of how assessment information was used to establish wetland condition classes for the SJB/NMF Project Area.

Estimates of wetland acreage

Acreage estimates for wetlands in the SJB/NMF Project area were statistically extrapolated from observations made at survey sample points. The estimates were computed using weights that are the inverse of the inclusion probabilities, and are equivalent to the number of acres in the target population that are represented by each site in the sample. Further details on the estimation of weighted population statistics are available in Diaz-Ramos et al. (1996), Li et al (1992) and Genet and Olsen (2008).

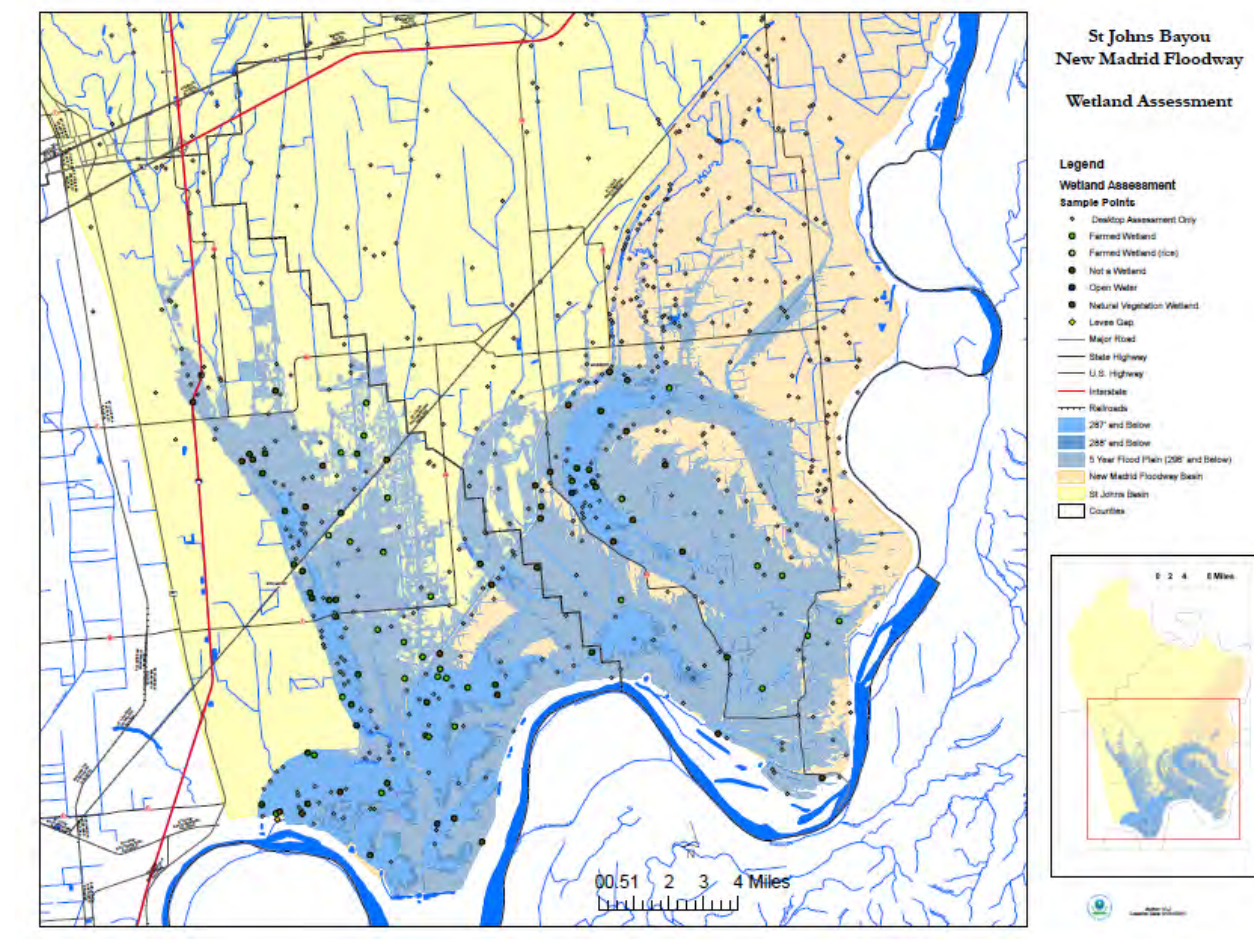
Table 7. SJB/NMF wetland acreage estimates for St. Johns Bayou and New Madrid Floodway Project areas

Total SJB/NMF Project Area (Five-Year Flood Zone and Non-Flood Zone)	Both Basins	St. Johns Bayou	New Madrid Floodway
Total wetland			
Natural Vegetated Wetland			
Agricultural land*			
Five-Year Flood Zones	Both Basins	St. Johns Bayou	New Madrid Floodway
Total wetland			
Natural Vegetated Wetland			
Agricultural land*			
Non- Flood Zones	Both Basins	St. Johns Bayou	New Madrid Floodway
Total Wetland			
Natural Vegetated Wetland			
Agricultural land*			

Table 7 presents acreage estimates for wetlands occurring in the different parts of the SJB/NMF Project Area. Each acreage estimate has an associated statistical confidence interval and confidence limit. For example, the acreage estimate for Natural Vegetated Wetlands located in the combined SJB “Five-Year Flood zone” and NMF Five-Year Flood Zone is XXXXXX acres. The confidence interval for this value is

approximately +/- XXXX acres. The confidence limit is 90%. From a statistical perspective, if the wetland assessment was conducted over and over again, then 90% of the time resulting value would be between XXXX and XXXXXX. From a practical perspective, the XXXXXX acre value is considered the “best estimate” because it is the value most likely to be produced in a repeated assessment. Likewise, multiple repeated assessments would like generate values very close to the XXXXXX value.

Figure 2. Map of data points and their results.



Placeholder for reporting acreage by different elevations. Need to provide request to Tony.

Table 8. acreage results by elevation in each in the St. Johns Bayou.

Elevation	Vegetated Wetland Acreage	Upper Confidence Interval	Lower Confidence Interval	Agricultural Land*	Upper Confidence Interval	Lower Confidence Interval
280						
281						
282						
283						
284						
285						
286						

287						
288						
289						
290						
291						
292						
293						
294						
295						
296						
297						
298						
299						
300						

Table 9. acreage results by elevation in each in the New Madrid Floodway.

New Madrid Floodway elevation	Vegetated Wetland Acreage	Upper Confidence Interval	Lower Confidence Interval	Agricultural Land*	Upper Confidence Interval	Lower Confidence Interval
278						
279						
280						
281						
282						
283						
284						
285						
286						
287						
288						
289						
290						
291						
292						
293						
294						
295						
296						
297						
298						
299						
300						

301						
302						
303						
304						
305						

Estimates of wetland condition

Prior to calculating estimates of wetland condition, the IWC variables within the IWC-Field Method were screened using the field data on wetland condition that was collected during the assessment. The screening approach was conducted in a way that is typically used to develop Indices of Biological Integrity (Klemm et al., 2003; Whittier et al., 2007; Stoddard et al., 2008), and as was specifically used for IWC development by Jacobs et al. (2010). The screening focused on variable performance with respect to redundancy and responsiveness. Results from the analysis were used to make refinements to both the IWC-Field Method and the IWC-Desktop Method.

Redundancy was evaluated to identify variables that are highly correlated with each other. Such variables contribute redundant information to the overall IWC, and can implicitly “double-weight” the significance of a wetland attribute for calculating an overall condition score. IWC variable redundancy was evaluated by calculating a Pearson correlation coefficient matrix among all the variables used in the IWC-Field Method. Variables correlated with an $r > 0.8$ are considered redundant.

The three variables, V_{STRATA} , V_{TDEN} , and V_{COMP} , were found to be highly correlated ($r=8.2-8.9$). This redundancy has the effect of triple-weighting the importance of the vegetation attribute of the IWC.

Responsiveness was evaluated to determine how well the IWC-Field Method variables were able to distinguish between sites that were categorized by their ecological condition. Condition categories were established by EPA staff using best professional judgment and are reported in **Table 10**.

Table 10. IWC scores attributed to wetland ecological condition classes as determined using best professional judgment

IWC Scores Natural Vegetated Wetlands	Ecological Condition Classes
69 and above	“Least disturbed:” Relatively large patch, forested wetland
47-68	“Disturbed and recovering:” Fragmented forest and/or relatively large patch herbaceous wetlands”
46 and below	“Highly disturbed,” Can include manipulated wetlands e.g. planted with corn for wildlife
IWC Scores “agricultural lands*”	Ecological Condition Classes
28 and above	“Relatively high restoration potential”
27 and below	“Relatively low restoration potential”

The analysis by EPA staff to establish condition classes was conducted by compiling a set of ground and aerial images of each survey site that was sampled within the SJB Five-Year Flood Zone and the NMF Five-year Flood Zone. The sites and their corresponding imagery were placed in ordered sequence according to their IWC scores (i.e., low to high). Separately, a set of narrative condition classes were defined for Natural Vegetated Wetlands and “agricultural lands*”. The definitions are based on EPA staff knowledge about wetland resources in the region. The definitions also take into account an understanding of how condition information can be used to inform mitigation determinations (See “Discussion” section). EPA staff applied the defined condition classes to the IWC ranked survey sites, and identified general breakpoints in IWC scores that reflected the defined condition classes.

The above described best professional judgment (“BPJ”) procedure produced a measure of wetland condition that is somewhat independent from the results of the IWC assessment. Box and whisker plots of the IWC variable scores in each of the disturbance classes were examined, and a one-way analysis of variance (ANOVA) was used to see if any of the variables had significantly different mean values among the disturbance classes. Variables with non-significant F-values from the ANOVA were deemed non-responsive. The risk of bias (“circular reasoning”) in the BPJ procedure was taken into consideration during the interpretation of results.

The two variables, V_{TRACT} and V_{CORE} , were found to be relatively unresponsive in their ability to discriminate the ecological condition of sites. On the other hand, V_{STRATA} , V_{POND} , $V_{CONNECT}$, and V_{GVC} were found to be very responsive at discriminating the condition classes.

Based on this analysis a decision was made by EPA to retain V_{STRATA} , V_{TDEN} , and V_{COMP} within the IWC Field Method. The rationale is that vegetation structure generally responds predictably to a wide range of stressors that affect wetland condition. Accordingly, the redundancy will not likely introduce bias in the reporting of results. However, the redundancy does provide a quality assurance check on the measurement of a significant wetland attribute (vegetation). In other words, in this situation the redundancy can aid measurement precision.

The condition classes defined for the SJB Five-Year Flood Zone and NMF Five-Year Flood Zone also were applied to the SJB Non-Flood Zone and the NMF Non-Flood Zone, respectively. However, the IWC threshold values between condition classes are different because of the differences between the IWC Field Method and the IWC Desktop Method. The threshold scores for the Non-Flood Zones were set at “75 and above” for least disturbed, “50-75” for disturbed and recovering, and “50 and below” for highly disturbed. These are “rule-of-thumb” breakpoints often used in the initial construction and testing of multi-metric indices for assessing aquatic resource condition (A.Herlihy, personal communication).

As described above, wetland condition scores for SJB Five-Year Flood Zone and the NMF Five-Year Flood Zone were calculated from data collected using the IWC-Field Method. Wetland condition scores for the SJB Non-Flood Zone and the NMF Non-Flood Zone were calculated from data collected using the IWC-Desktop Method. The results are presented in **Table 9**. In examining the results, a significant discrepancy is shown between the condition profiles of the 5-Year Flood Zones and Non-Flood Zones. For example, 40% of the natural vegetated wetlands in the combined SJB and NMF Five-Year Flood Zones are reported in least-disturbed condition. However, only 4% of the natural vegetated wetlands in Non-Flood Zones are reported in that condition class. These results suggest that the thresholds used for IWC-Desktop method are in need of adjustment. The need for adjustment is attributed to use of fewer and less robust variables as compared to the IWC-Field Method. The adjustment can be made using the

BPJ procedure described above. In the alternative, an assumption can be made that the condition profile of wetlands in the Five-Year Flood Zones and the Non-Flood Zones is comparable.

Table 11. Estimates of percentage of wetland acreage in a condition class for each zone of the SJB/NMF Project area. No assessment or estimates were made of the condition of “agricultural lands*” in the SJB Non-Flood Zone and the NMF Non-Flood Zone. **After re-running numbers do these values hold?**

Natural Vegetated Wetland /Condition Class	Least Disturbed	Disturbed Recovering	Highly Disturbed
Combined SJB and NMF Five-Year Flood Zone	40%	36%	24%
SJB Five-Year Flood Zone	26%	53%	21%
NMF Five-Year Flood Zone	51%	23%	26%
Combined SJB and NMF Non-Flood Zone	4%	22%	74%
SJB Non-Flood Zone	4%	20%	76%
NMF Non-Flood Zone	5%	45%	50%
“Agricultural Lands*” /Condition Class	Relatively High Restoration Potential	Relatively Low Restoration Potential	
Combined SJB and NMF Five-Year Flood Zone	12.5%	87.5%	
SJB Five-Year Flood Zone	9.5%	90.5%	
NMF Five-Year Flood Zone	14%	86%	

Discussion

The SJB/NMF Wetland Assessment generated estimates of wetland acreage and wetland condition in the SJB/NMF Project area. The information will be used along with other information to assess project impacts and for making a determination of compensatory mitigation needs. **Table 12** presents an approach for connecting the amount and type of project impacts to wetlands with the amount of

Table 12. Hypothetical wetland mitigation schedule

Table 2-1. Hypothetical Wetland Mitigation Schedule

HYPOTHETICAL WETLAND MITIGATION SCHEDULE FOR SJB/NMF PROJECT			
WETLAND TYPE AND CONDITION	TYPE OF IMPACT		
	Direct -- Dredge/Fill	Direct -- Loss of Hydrology	Indirect -- Altered Hydrology
Natural Vegetated Wetland			
Good Condition	3:1 Restoration	2:1 Restoration	2:1 Enhancement
Degraded Condition	1:1 Restoration	2:1 Enhancement	1:1 Enhancement
“Agricultural Lands*”			
Ambient Condition	1:1 Restoration	Minimization and use of full mitigation ratios for other impacts	
Assumptions:			
1. Mitigation ratios are accounted by acres,			
2. Mitigation means that restored and enhanced wetlands will attain “good” ecological condition as measured using approved performance standards,			
3. The type of wetlands restored and enhanced will be consistent with the watershed profile of the project watershed area,			
4. Restored and enhanced wetlands will be sustainable because of their proper placement in the project watershed area,			
5. Higher ratios account for uncertainty of mitigation success and cumulative impacts attributed to project effect on Non-Flood Zones of the project watershed area,			

6. Proposed hydrologic connectivity between the Mississippi River and Big Tree State Park is an example of “enhancement” mitigation,
7. A major risk attributed to “loss of hydrology” is the loss of regulatory protection over the impacted wetland resource, and
8. The mitigation schedule does not account for stream mitigation needs. A separate schedule can be developed for impacts to that type of aquatic resource (e.g., use Missouri Stream Mitigation Method)

compensatory mitigation with the amount of compensatory mitigation needed to offset the functional loss caused by impacts. The table also includes a set of assumptions that can guide the use of the assessment framework.

The assessment framework depicted in Table 12 is based on provisions outlined in the federal Compensatory Mitigation Rule (USCOE and USEPA, 2008). In particular, the Rule stipulates use of a watershed approach to guide mitigation determinations. The watershed approach takes into account the abundance, types and condition of aquatic resources in a project watershed area. The theoretical basis for this accounting is that those three attributes affect landscape function and the delivery of benefits provided by wetlands (Bedford 1996, Bedford 1998). Wetland abundance, types and condition can be graphically depicted as a ‘wetland landscape profile’ (Johnson, 2005) or as “watershed profile” (Kittel and Faber-Langendoen, 2011).

In turn, the described ecological theory supports a criterion that compensatory mitigation should be accomplished in a way that sustains and improves the abundance, types and condition of wetlands in a project watershed area. In other words, one acre of wetland loss generally requires one acre of wetland restoration of the same wetland type that was impacted. One acre of wetland degradation requires one acre of wetland enhancement. Adjustments are made to those basic ratios to address the various risks associated with the achievement of successful mitigation. For example, the higher ratios depicted in Table 12 reflect the risk of mitigating the loss and degradation of wetlands in “good condition” that are located in a hydrologically disturbed landscape. It will be difficult to restore and enhance mitigation wetlands to levels of good condition. The ratios also take into account standard operating procedures (ratios) used by federal and state regulators in the Project area.

In summary, information generated by the SJB/NMF Wetland Assessment can be used to describe the current watershed profile of the SJB/NMF project watershed area. The current watershed profile serves as a baseline for comparison with a predicted future watershed profiles as would be generated by proposed Corps of Engineers’ Project alternatives. A comparison of current and future watershed profiles can be used to guide mitigation needs analysis.

References

Bedford, B.L. 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. *Ecological Applications* 6: 57-68.

<http://www.jstor.org/sici?sici=10510761%281996%291%3C57%3ATNTDHE%3E2.0.CO%3B2-x&cookieSet=1>

Bedford, B. 1999. Cumulative effects on wetland landscapes: links to wetland restoration in the United States and Southern Canada. *Wetlands* 19: 775-788.

<http://www.eli.org/pdf/wsSymposium/AppendixA/bedfordpaper.pdf>

Johnson, J. Bradley. 2005. Hydrogeomorphic wetland profiling. An approach to landscape and cumulative impacts analysis. EPA/620/R-05/001. U.S. Environmental Protection Agency, Washington D.C. <http://www.epa.gov/owow/wetlands/pdf/Johnson-HGMPprofiling2005.pdf>

Kittel, G. and D. Faber-Langendoen. 2011. Watershed Approach to Wetland Mitigation: A Proposed Conceptual Framework for Juneau, Alaska. Prepared by NatureServe, Arlington VA

Fennessy, M.S., A.D. Jacobs, M.E. Kentula. An evaluation of rapid methods for assessing the ecological condition of wetlands. *Wetlands* 27(3) pp 543-560.

Genet, J. A., and Olsen, A. R. (2008), "Assessing Depressional Wetland Quantity and Quality Using a Probabilistic Sampling Design of in the Redwood River Watershed, Minnesota, USA," *Wetlands*, 28, 324–335.

Jacobs, A. D., Kentula, M. E., & Herlihy, A. T. (2010). Developing an index of wetland condition from ecological data: An example using HGM functional variables from the Nanticoke watershed, USA. *Ecological Indicators*, 10:3:703-712.

Kittel, G. and D. Faber-Langendoen. 2011. Watershed Approach to Wetland Mitigation: A Proposed Conceptual Framework for Juneau, Alaska. Prepared by NatureServe, Arlington VA

Klemm, D.J., Blocksom, K.A., Fulk, F.A., Herlihy, A.T., Hughes, R.M., Kaufmann, P.R., Peck, D.V., Stoddard, J.L., Thoeny, W.T., Griffith, M.B., Davis, W.S., 2003. Development and evaluation of a macroinvertebrate biotic integrity index (MBII) for regionally assessing Mid-Atlantic Highlands streams. *Environ. Manage.* 31, 656–669.

Klimas, C.V., Murray, E.O., Pagan, J., Langston, H., and Foti, T. (2009). "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley," U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Li, H. G., Schreuder, H. T., VanHooser, D., and Brink, G. E. (1992), "Estimating Strata Means in Double Sampling with Corrections Based on Second-Phase Sampling," *Biometrics*, 48, 189-199.

NRCS. 1995. Missouri Wetland Mapping Conventions. USDA National Resources Conservation Service. Columbia, MO.
<http://www.mo.nrcs.usda.gov/technical/out/MissouriWetlandMappingConventions.pdf>

MN BWSR. 2010. Wetland Conservation Act: Using aerial imagery to assess wetland hydrology. BWSR Technical Guidance, July 1, 2010.
http://www.bwsr.state.mn.us/wetlands/wca/Using_Aerial_Imagery_to_Assess_Wetland_Hydrology7-1-10.pdf

Paulsen, S.G., D.P. Larsen, P.R. Kaufmann, T.R. Whittier, J.R. Baker, D. Peck, J. McGue, R.M. Hughes, D. McMullen, D. Stevens, J.L. Stoddard, J. Lazorchak, W. Kinney, A.R. Selle, and R. Hjort. 1991. EMAP - surface waters monitoring and research strategy, fiscal year 1991. EPA-600-3-91-002. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. and Environmental Research Laboratory, Corvallis, Oregon

Saucier, R. L. (1994). "Geomorphology and quaternary geologic history of the Lower Mississippi Valley," Vol I (report), Vol II (map folio), U.S. Army Engineer Waterways Experiment Station, Vicksburg MS.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. *Wetlands*

Research Program Technical Report WRP-DE-9. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Stoddard, J.L., Herlihy, A.T., Peck, D.V., Hughes, R.M., Whittier, T.R., Tarquinio, E., 2008. A process for creating multimetric indices for large-scale aquatic surveys. *J. N. Am. Benthol. Soc.* 27, 878–891

Saucier, R. T. 1994. Geomorphology and Quaternary geologic history of the lower Mississippi valley (scale 1:250,000). Volume I: Text. Volume II: Map folio (28 plates). U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Stevens, D. L., Jr., 1994. Implementation of a National Monitoring Program. *Journal Environ. Management* 42:1-29

U.S. Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual. Technical Report Y-87-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

U.S. Army Corps of Engineers. 2010. Regional Supplement to the Corps of Engineers Wetlands Delineation Manual: Atlantic and Gulf Coastal Plain Region (Version 2.0), ed. J. S. Wakeley, R. W. Lichvar, and C. V. Noble. ERDC/EL TR-10-20. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

U.S. Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA). 2008. *Compensatory Mitigation for Losses of Aquatic Resources; Final Rule*. 33 CFR Parts 325 and 332 and 40 CFR Part 230. Published in Federal Register April 10, 2008.

Whittier, T.R., Hughes, R.M., Stoddard, J.L., Lomnický, G.A., Peck, D.V., Herlihy, A.T., 2007. A structured approach for developing indices of biotic integrity: three examples from western USA streams and rivers. *Trans. Am. Fish. Soc.* 136, 718–735.

ATTACHMENT "A"

DESCRIPTION OF IWC VARIABLES

St. Johns Bayou and New Madrid Floodway Wetland Assessment

The methods use an "Index of Wetland Condition ("IWC"). The U.S. Army Corps of Engineers Engineer Research and Development Center ("ACE-ERDC") prepared a September 29, 2010 description of the IWC. This document describes refinements made to the IWC by EPA based on a statistical analysis of the performance of IWC variables.

We need to reconcile notes in red.

IWC Variables (Condition Metrics)

The variables described in this attachment comprise the IWC-Field Method and the IWC-Desktop Method that were used in the St. Johns Bayou and New Madrid Floodway Wetland Assessment. Figure 1 depicts a typical mapped scene within the Project Area. The first three variables reflect the occurrence of a buffer around an assessment area that was selected within that scene.

V_{TRACT} - Wetland Tract (Check Phase 1-205 farmed wetlands. It has a V_{tract} score) need to look at data sheet for in-office portion and GIS to see if there are any notes on why there was a V_{tract} for a farmed wetland).

This landscape variable is assessed the same way in the IWC-Field Method and the IWC-Desktop Method. It is defined as the area of contiguous Natural Vegetated Wetland that includes the 0.5-ha assessment area (Figure 2). Forested, shrub, or herbaceous wetlands were included in the Wetland Tract, *except* "agricultural lands*", moist soil units, or other areas managed for a particular wildlife habitat purpose. Adjacent wetlands do not have to be in the same regional subclass as the assessment area to be part of the wetland tract.

Procedure:

- (1) Determine the size of the natural vegetated wetland area in hectares that is contiguous to the 0.5-ha assessment area (including the 0.5-ha assessment area itself). Use topographic maps, aerial photography, GIS, field reconnaissance or another appropriate method.
- (2) Record the natural vegetated wetland tract area in hectares on the Data Reporting Form in the Variable Value box of the V_{TRACT} row.

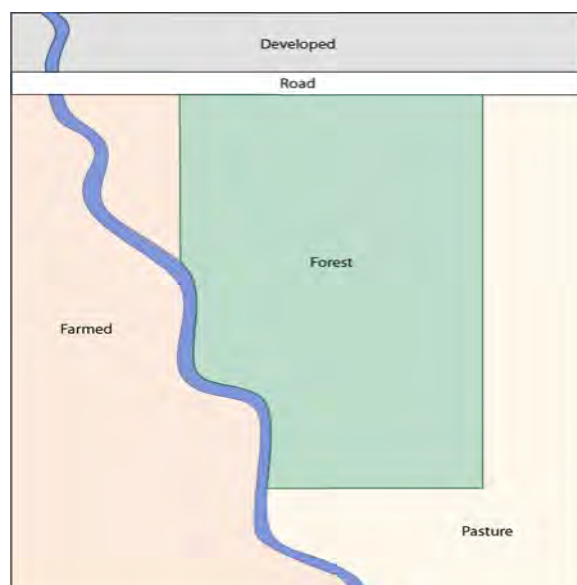


Figure 1. Land cover

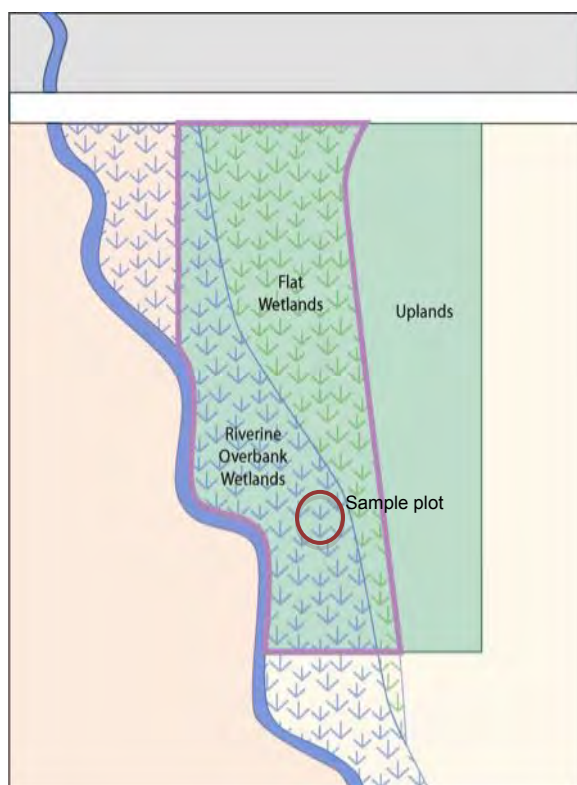


Figure 2. Wetland subclasses (purple line indicates extent of the "wetland tract")

- (3) Using the scaling “initial” curve for the appropriate subclass in Attachment B, enter the Variable Subindex in the last box of the V_{TRACT} row.

V_{CORE} - Core Area

This variable is determined the same way for the IWC-Field Method and the IWC-Desktop Method. This variable is defined as the portion of a wetland tract that lies to the inside of a 100-m (330-ft) buffer interior of the boundary of the entire natural vegetated wetland area (Figure 3). The percentage of a wetland tract that lies to the inside of this 100-m (330-ft) buffer zone is the metric used to quantify this variable. Note that the tract is not limited to the 0.5-ha assessment area, but includes all contiguous natural-vegetated wetlands.

Procedure:

- (1) On a map or photo, draw a continuous line 100 m inside the boundary of the entire contiguous natural vegetated wetland area.
- (2) Calculate the size of the wetland tract that lies inside this line. This is the core area.
- (3) Divide the size of the core area by size of the wetland tract and multiply by 100 to calculate the percent of the wetland tract that is core.
- (4) Record the percentage on the Data Reporting Form in the Variable Value box of the V_{CORE} row.
- (5) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the V_{CORE} row.

$V_{CONNECT}$ – Landscape Connectivity

This variable was measured the same way for both the IWC-Field Method and the IWC-Desktop Method. This variable is defined as the proportion of the perimeter of a Natural Vegetated or “agricultural lands*” tract that is connected to upland forests or other natural vegetated wetlands (Figure 4). Agricultural fields, orchards, clear cuts, pastures dominated by non-native species, mined areas, and developed areas are examples of unsuitable land cover types.

The percentage of the natural vegetated wetland tract boundary that is “connected” is used to quantify this variable. Note that the “tract” is not limited to the 0.5-ha assessment area under consideration, but includes all contiguous forested wetlands (Figure 2). An

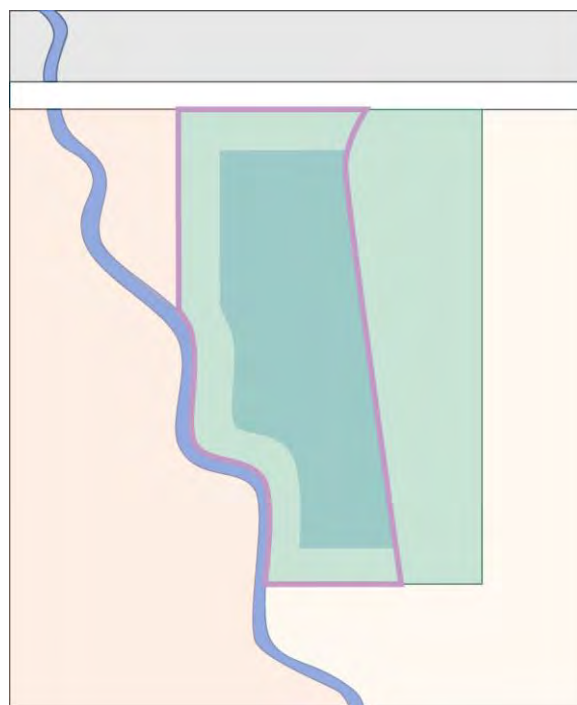


Figure 3. Identification of “core area.” Refer to Figure 1 for subunit designations



Figure 4. Identification of “connected perimeter” (green line).

adjacent area is considered connected if it is within 0.5 km (0.31 mile) of the boundary of the natural vegetated assessment area.

Procedure

- (1) Calculate the length of the natural vegetated wetland assessment area boundary. Use field reconnaissance, topographic maps, aerial photography, GIS, or another suitable method or tool.
- (2) Calculate the length of the natural vegetated wetland assessment area that is within 0.5 km (0.31 mile) of buffer land cover types as previously described.
- (3) Divide the length of connected natural vegetated wetland assessment area boundary by the length of the total natural vegetated wetland assessment area boundary, and then multiply by 100. The resulting number is the percent of the natural vegetated wetland assessment area boundary that is connected.
- (4) Record this percentage on the Data Reporting Form in the Variable Value box of the $V_{CONNECT}$ row.
- (5) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the $V_{CONNECT}$ row.

V_{POND} - Total Ponded Area

This variable was only measured using the IWC-Field Method. Total Ponded Area refers to the percent of the 0.5-ha assessment area ground surface likely to collect and hold precipitation for periods of days or weeks at a time. (Note: This is distinct from the area that is prone to flooding, where the surface of the 0.5-ha plot is inundated by overbank or backwater connections to stream channels). The smaller (microtopographic) depressions are usually a result of tree “tip ups” and the scouring effects of moving water, and typically they are between 1 and 10 m² in area. Larger vernal pools (usually at least 0.04 ha) occur in the broad swales typical of meander scroll topography, or in other areas where impeded drainage produces broad, shallow pools during rainy periods. The wetlands where these features are important typically have a mix of both the small microdepressions and the larger vernal pools.

Procedure:

- (1) Conduct a field reconnaissance of the entire 0.5-ha assessment area, estimate the percentage of the assessment area surface having microtopographic depressions and vernal pool sites capable of ponding rainwater. Base the estimate on the actual presence of water immediately following an extended rainy period if possible, but during dry periods use indicators such as stained leaves or changes in ground vegetation cover. Generally, it is not difficult to visualize the approximate percentage of the area subject to ponding, but it is important to base the estimate on a walkover of the entire assessment area.
- (2) Report the percent of the assessment area subject to ponding on the Data Reporting Form in the Variable Value box of the V_{POND} row.
- (3) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the V_{POND} row.

Note that, in the case of the Flats subclass, Data Reporting Form 3 also requires identification of the geomorphic surface on which the 0.5-ha sample plot is located, because percent ponding differs markedly among surfaces in the reference data set, which is reflected in the scaling curves.

The geomorphic surface can be identified using the digital version of the geomorphology map (Saucier 1994) in ArcMap. Assign the 0.5-ha sample plot to one of two possible surfaces found within the project area:

- Pleistocene Valley Train deposits (formed by glacial outwash events), identified as map unit codes that begin with the letters Pv or Ps in Saucier's map.
- Holocene Alluvium (post-glacial meander belts), identified as map unit codes that begin with the letter H in Saucier's map.

V_{STRATA} - Number of Vegetation Strata

This variable was only measured using the IWC-Field Method. The number of vegetation layers (strata) present in Natural Vegetated Wetlands reflects the ecological structure of the assessment area.

Procedure:

- (1) Conduct a field reconnaissance of the entire 0.5-ha assessment area, identify which of the following vegetation layers are present and account for at least 10 percent cover, on average, throughout the site.
 - Canopy (trees in the canopy layer greater than or equal to 10 cm dbh).
 - Subcanopy (trees below the canopy layer greater than or equal to 10 cm dbh. Recognize this layer if it is distinctly different from a higher, more mature canopy).
 - Understory (shrubs and saplings less than 10 cm dbh but at least 4.5 ft tall).
 - Ground cover (woody plants less than 4.5 ft tall and herbaceous vegetation).
- (2) Enter the number of vegetation strata (0 – 4) present on the Data Reporting Form in the Variable Value box of the V_{STRATA} row.
- (3) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the V_{STRATA} row.

$V_{TOPSTRATUM}$ - Top Vegetation Stratum

This variable was measured only using the IWC-Desktop Method.

Procedure:

- (1) Draw a 0.5-ha plot around the point on an aerial photo, and identify which of the following vegetation layers is the top stratum, with at least 10 percent cover, on average, throughout the site.
 - Trees
 - Shrubs
 - Herbs (may include seedlings of woody plants less than 4.5 ft)
- (2) Enter the top vegetation stratum (Trees, Shrubs, Herbs) present on the Data Reporting Form in the Variable Value box of the $V_{TOPSTRATUM}$ row.

- (3) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the $V_{TOPSTRATUM}$ row.

V_{CTDEN} - Canopy Tree Density

This variable was measured using the IWC-Desktop Method. However, field sample sites within the Flood Zone parts of the Project Area were measured to scale the variable. Canopy tree density is the number of canopy trees (i.e., living woody stems greater than or equal to 10 cm or 4 in. that can be seen in an aerial photograph) per unit area. The density of tree stems per hectare is the metric used to quantify this variable.

Procedure:

- (1) Draw a 0.5-ha assessment area around the sample point on an aerial photo. Count the number of tree crowns visible within the within the 0.5-ha assessment area. Measure the assessment area radius to all marginal trees, and include only trees having at least half the crown within the assessment area.
- (2) Record the crown count on the Data Reporting Form in the right hand end of the Procedure box of the V_{CTDEN} row. Multiply by 2 to calculate stems/ha, and record that value in the Variable Value box of the V_{CTDEN} row.
- (3) Use the ratio of Canopy Tree Density to Tree Density at field sites to adjust the scaling curve for the appropriate subclass in Appendix 2, to be used to determine Variable Subindices for aerial photo interpretation sites. Enter the Variable Subindex in the last box of the V_{CTDEN} row.

V_{TDEN} - Tree Density

This variable was measured using the IWC-Field Method. Tree density is the number of trees (i.e., living woody stems greater than or equal to 10 cm or 4 in.) per unit area. The density of tree stems per hectare is the metric used to quantify this variable.

Procedure:

- (1) Randomly place a center point for a nested 0.04-ha plot (with a radius of 11.35m or 37.3 ft) within the assessment area. Count the number of tree stems within the 0.04-ha plot. Measure the plot radius to all marginal trees, and include only trees having at least half the stem within the plot.
- (2) Record the stem count on the Data Reporting Form in the right hand end of the Procedure box of the V_{TDEN} row. Multiply by 25 to calculate stems/ha, and record that value in the Variable Value box of the V_{TDEN} row.
- (3) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the V_{TDEN} row.

V_{GVC} - Ground Vegetation Cover

This variable was measured using the IWC-Field Method. Ground vegetation cover is defined as herbaceous and woody vegetation less than or equal to 1.4 m (4.5 ft) in height. The percent cover of ground vegetation is used to quantify this variable.

Procedure:

- (1) Visually estimate the proportion of the ground surface in the assessment area that is covered by ground vegetation by mentally projecting the leaves and stems of ground vegetation to the ground surface. Do this in each of four 1-m² subplots placed 5 m (15 ft) from the center of the assessment area, one in each cardinal direction, and record in the right hand end of the Procedure box for the V_{GVC} row. Average these subplot values and enter it in the Variable Value box of the V_{GVC} row. Alternatively, the entire 0.5-ha assessment area may be walked over and a cover estimated, and entered in the Variable Value box of the V_{GVC} row.
- (2) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the V_{GVC} row.

V_{COMP} - Composition of Tallest Woody Vegetation Stratum

This variable was measured using the IWC-Field Method. This variable represents the plant species composition of the tallest woody stratum present in the assessment area. This could be the tree, shrub-sapling, or seedling stratum. Percent concurrence with reference wetlands of the dominant species in the dominant vegetation stratum is used to quantify this variable.

Procedure:

- (1) Identify the top vegetation stratum that comprises at least 10% cover.
- (2) Within this stratum, identify the dominant species based on percent cover using the 50/20 rule (U.S. Army Corps of Engineers 1992): rank species in descending order of percent cover and identify dominants by summing relative dominance in descending order until 50 percent is exceeded; additional species with 20 percent relative dominance should also be included as dominants. Circle these species on page 2 of the Data Reporting Form under the appropriate wetland subclass. Accurate identification of woody species is critical for determining the dominant species in each assessment area. Sampling during the dormant season requires proficiency in recognizing plant form, bark, and dead or dormant plant parts.
- (3) Calculate percent concurrence using the formula provided at the bottom of Page 2 of the Data Reporting Form, which weights dominant species based on their likelihood of being dominant in reference stands of varying condition. The result is intended to indicate the character of the developing natural vegetated wetland.
- (4) Record the percent concurrence value in the in the Variable Value box of the V_{COMP} row.
- (5) Using the scaling curve for the appropriate subclass in Appendix 2, enter the Variable Subindex in the last box of the V_{COMP} row.

Notes on adapting the plant-related variables to the SJB/NMF Project Area

Additional Species: After conducting fieldwork, several species were added to the V_{COMP} lists. *Quercus macrocarpa* (bur oak) and *Fraxinus profunda* (pumpkin ash) are more prevalent as one moves north within the Mississippi Alluvial Valley, and seen in the project area. In addition, *Quercus palustris* (pin oak) is common north of the project area, but appears to be hybridizing with *Quercus nuttallii* within the project area. All of these species were entered into the A column, where the majority of oaks and

hickories reside. Several light-seeded species are common in Riverine Backwater sites, as well as Riverine overbank sites, where they would have been expected based strictly on Arkansas data. These species included *Acer saccharinum* (silver maple), *Populus occidentalis* (cottonwood), and *Betula nigra* (birch). These species are frequently found in riverine forests, but are not generally dominant unless there has been some sort of disturbance, such as logging. These species were placed in the B column, which is where they were already listed for Riverine Overbank sites.

Richard
Sumner/COR/USEPA/US

04/18/2011 12:18 PM

To Brad Horchem

cc

bcc

Subject Re: Fw: SJNM NRCS Criteria (UNCLASSIFIED)

Hi Brad

A few comments on the information you sent.

1. Overall, the NRCS analysis focused on assessing the extent of "farmed wetlands" as defined for Farm Securities Act purposes. I assume the reason why NRCS conducted the estimate was to evaluate the extent that the proposed SJB/NMF project would impact the eligibility of agricultural producers to receive farm benefits including WRP/CRP payments. That is a different objective than an assessment of the size in area and the ecological condition of wetlands area would be impacted by the project.

2. The NRCS analysis does not provide indication of what amount of "farmed wetland" acreage would revert to natural vegetated wetland if left un-farmed. The "farmed wetland" areas that would revert to naturally vegetated wetlands are regulated on CWA Section 404.

3. The NRCS analysis (**excerpt below**) explains that three one-mile wide transects were evaluated for accuracy of an "original wetland inventory." Aerial photos were used. There is no detailed information about how the actual analysis was conducted. Rather, it is stated that:

"None of slides available for our sampling showed any widespread affects of backwater flooding or river level stages that would initiate gate closure for the Saint John's Bayou (no headwater flooding was observed.) Most wetland signatures were due to inundation or moisture do to precipitation & local flooding events."

I believe that the information provided is insufficient information to make a determination that the area is not affected by backwater flood event, nor that farmed wetland areas would not convert to natural vegetated wetlands if left unfarmed.

From ecological perspective, major flood events will affect the landscape structure of the project area in a way that influences the acreage amount of wetlands in the project area. In other words, some wetlands that appear to be supported only by precipitation and local flooding events actually require hydrological connectivity to the mainstem river to sustain their hydrogeomorphical characteristics over time (e.g., morphology and substrate).

4. The survey sample frame for the Lower Yazoo Basin Wetland Assessment was generated from the (1) FEAT delineated area, (2) NLCD forested area + WRP lands and (3) "Low Potential Lands." Survey sample points were allocated to each strata. Low Potential Lands are all lands that are not (1) or (2). The "Low Potential Lands" strata is somewhat analogous to the combining of the "Cropland" and "Development" NLCD strata, as applied to the SJB/NMF design.

5. At some point the description of project "scenarios" should include estimates of wetland acreage impacted, and of course specificity. The current descriptions are anecdotal.

Rich

(FEAT delimited area, NLCD forested areas and WRP lands, and the area not included in

the first two categories (Low Potential)

Follow-up Actions:

NRCS assembled a three person team and evaluated the original wetland inventory (within the COE's project area) from September 26-29, 2005 for its use in the planning stage.

The COE estimated/identified impacted farmed wetlands (backwater flooding in the Madrid floodway and headwater flooding in the St. John Bayou) using an elevation of 290.5 feet. This elevation was chosen as a conservative level and is noted in the impact statement.

Staff assembled remote sensing resource materials and noted the climatic conditions.

- A. Mississippi County – Farm Service Agency “compliance inventory” used three (3) wet and two (2) dry/normal years. Aerial photographs (dry), soil survey (dry), 1980 wetland inventory (dry), March 1990 Farm Service Agency base maps (dry), and June 2003 color infrared aerial photograph (dry).
- B. New Madrid County – Farm Service Agency “compliance inventory” used two (2) wet and two (2) dry/normal years. Aerial photographs (normal), 1980 wetland inventory (dry), March 1990 Farm Service Agency base maps (dry), and June 2003 color infrared aerial photograph (dry).

We selected three one-mile wide transects/sample areas to evaluate the accuracy and applicability to the Wetland Conservation provisions (the sample areas represent the project area as outlined by the COE):

1. Transect #1 – East edge starts at: T. 24 N., R. 14 E., Section 11 and ends at: T. 24 N., R. 17 E., Section 10 (~17 ½ miles).
2. Transect #2 – East edge starts at: T. 23 N., R. 15 E., Section 6 and ends at: T. 23 N., R. 17 E., Section 2 (~17 miles).
3. Transect #3 – East edge starts at: T. 23 N., R. 14 E., Section 35 and ends at: T. 23 N., R. 17 E., Section 35 (~7 miles).

Findings:

Our sampling shows the original wetland inventory to be adequate for delineating wetlands (FW) for planning purposes in the project area.

None of the slides available for our sample showed any wide spread effects of flooding or river level stages that would initiate gate closure for the St. John headwater flooding was observed). Most wetland signatures were due to increased moisture due to precipitation & local flooding events.

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Brad Horchem

Rich, With all of the discussions going on with Pr...

04/18/2011 07:26:21 AM

From: Brad Horchem/R7/USEPA/US
To: Richard Sumner/COR/USEPA/US@EPA
Date: 04/18/2011 07:26 AM
Subject: Fw: SJNM NRCS Criteria (UNCLASSIFIED)

Rich,

With all of the discussions going on with Prior Converted Cropland and Farmed Wetlands, below is information we received from the Corps that they received from NRCS on how they came up with their numbers. Please review and provide feedback.

Brad Horchem
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----- Forwarded by Brad Horchem/R7/USEPA/US on 04/18/2011 09:14 AM -----

From: "Ward, Daniel D MVM" <Daniel.D.Ward@usace.army.mil>
To: Brad Horchem/R7/USEPA/US@EPA, Joe Cothorn/R7/USEPA/US@EPA
Cc: "Williams, Gregg W MVM" <Gregg.W.Williams@usace.army.mil>, "Koontz, Joshua MVM" <Joshua.M.Koontz@usace.army.mil>
Date: 02/25/2011 01:34 PM
Subject: SJNM NRCS Criteria (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

I've attached two files from NRCS regarding analysis that concludes majority of land in project area is PC.

1. NRCS Correspondence - I cut these directly out of the 2006 RSEIS 2. The entire document can be found in its entirety at:

<http://www.mvm.usace.army.mil/StJohns/Studies/default.asp>

2. NRCS_FWProcedures - letter from NRCS to the Justice Department.

Brad - could you please forward to Vicky and Jason. My hard drive got zapped and I no longer have their email addresses readily available.

Also - is it possible for you to send me the Yazoo wetland report that Region 4 did for Vicksburg District. The version I have (attached) states that farmland was not targeted in the analysis.

As far as alternatives, we are analyzing the authorized project and avoid and minimize measures.

The authorized project calls for closing New Madrid Gates at an elevation 275 feet NGVD, turning pumps on at 278 and turning pumps off at 275 (this is well within channel). Overbank flooding does not occur until an elevation of approximately 280. In addition gates would be used to inundate lower elevations found in the Floodway up to an elevation of 284 feet during waterfowl season (1 Dec to 31 January).

After much coordination with the sponsor, discussions held during interagency team meetings, public meeting, and the extensive feedback we received from the independent panel of experts; at present we are analyzing the following scenarios. Please note these are considered preliminary and there are multiple other factors that we are putting into the equation. The goal is to manage economic risk and environmental impacts by taking into account the different economic risks throughout the year in conjunction with the timing of the flood pulse in relation to environmental factors.

Scenario 1 - From Nov 15 - Feb 28 allow interior elevation to reach a maximum elevation of approximately 289.5 (note that this is 12 feet higher than the authorized project - roughly 23,000 acres). Roads start going underwater at an approximate elevation of 290, thus isolating residences in the Floodway. We still intend to hold water for waterfowl during waterfowl season. However, we would allow additional flooding if the river was at a higher elevation. To manage for this scenario (have to consider timing of pumps, closure, etc, and allow ample interior flood storage), gates would be closed at an elevation of approximately 288 with a pump start at 289.5 and a pump stop at 288.5. Allowing water to inundate at these elevations should dramatically lower impacts to waterfowl and keep the majority of the lower Floodway seasonally connected to the river.

During March 1 - April 15 the maximum flood elevation would be lowered to an elevation of 288 (gates closed at 286, pump on at 288, pump off at 287). The elevation of 288 is selected for a variety of reasons. First, it corresponds to the WETSORT elevation. Our attempt is to allow for connectivity with the

remaining wetlands found below this elevation. Second, by looking at the stage area curve the vast majority of forested lands within the Floodway are below this elevation. We are striving to reach balance between environmental impacts and economic benefits. Third, these dates correspond to early part of fish period, shorebirds, and the early part of the growing season (wetland/floodplain functions). Although the river typically floods at any time during December to June, the highest stages/prolonged floods typically occur during March to mid-April. I want to be clear that there will still be an environmental impact above these stages during this time period. However, there are also socioeconomic benefits. Roads stay open, people can access and plant fields at the higher elevations. Within the project area, corn needs to be planted in April. Losses in yield are correlated to delayed planting dates. Bottom line - ag areas above 288 could plant corn or any other crop (including double crop of early bean/winter wheat/late bean) that requires early planting without a large risk of flooding. For those below the line, you are taking a higher risk.

During April 15 to May 30, maximum flood elevation would be reduced to an elevation 284 (gates closed at 284, pump on at 284, and pump off at 282). May 1 is the cut off time for remaining agricultural commodities (rice, cotton, soybeans). Delayed planting after the first part of May starts impacting yield. We need to start drawing down in mid-April to allow for adequate drying of fields to be planted during the first part of May (in the event of high water it would take approximately 5 days to pump down, that leaves an approximate window of 1.5 weeks for drying - still a risk to farmers if we have prolonged rains). This time period still corresponds to seasonal high water and therefore, there will be an environmental impact. However, there are significant economic benefits. Bottom line - if you are between 284-288 you will not be taking a large risk to plant your fields at May 1. If you are below 284, there is still a risk.

During June 1 to Nov 14 - maximum flood elevation would be reduced to 280 (close gate at 278.5, pump on at 284, pump off at 278.5). Late season floods still occur but do not typically occur at frequencies we see during earlier parts of the year. However, these floods are of great concern to area producers. Because they don't occur as frequent, most farmers have previously planted fields, applied fertilizer, etc. (i.e., they have put a large investment in farming). Late season floods (like what was seen last year) typically relate to a total failure for that year. Please note our economic analysis also considers flood frequency. Bottom line - if you have planted any fields prior to June 1 you have a minimal risk of losing your crop.

Scenario 2 is the same as Scenario 1, except all maximum flood elevations are reduced by 2 feet.

Both of these scenarios may be adjusted over the course of the next several weeks and or new scenarios developed.

These scenarios are a far cry from what has been proposed in the past. We don't know if they will produce a positive benefit:cost because we may be leaving a good bit of economic benefits on the table. However, on the flip side, we should drastically reduce impacts and thus lower mitigation costs. I am still tweaking some additional aspects of the scenario. For example, I think it is a great idea to implement some sort of switchgrass option. This could definitely help specific farms that are located below 288. The biggest hurdle we are facing is that it is difficult for USACE to implement this program (better for USDA or Dept of Energy). However, we are trying to tie

it into a mitigation measure because switchgrass stubble is of higher habitat value when flooded for fish than barren ground. We are looking at purchasing limited restrictive easements on property on a voluntary basis below elevation 288. The easement will likely have to expire after a certain timeframe. Best case scenario - switchgrass will take off in the project area and industry/market follows (although we can't speculate and won't be taking any economic benefits for it). Worse case - we mitigate for a portion of the project impacts.

Lastly, we are going to propose an extensive adaptive management program that will re-visit the operation of the project at prescribed periods over the 50-year project life with some pretty extensive monitoring protocols.

Let us know if you need any other info at the present,

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Classification: UNCLASSIFIED
Caveats: NONE

[attachment "NRCS_correspondence.pdf" deleted by Richard Sumner/COR/USEPA/US]
[attachment "NRCS_FWProcedures_2006.pdf" deleted by Richard
Sumner/COR/USEPA/US] [attachment "Appendix%2010%20%20Supplement%20A%20.pdf"
deleted by Richard Sumner/COR/USEPA/US]

Attachment D
Comments of the Conservation Organizations

On the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)

Comments on the July 2013 Draft Environmental Impact Statement for the St. Johns Bayou and New Madrid Floodway Project Fisheries Impacts and Mitigation

Richard E. Sparks, Ph.D.
24 November 2013

1. Introduction

I recently retired as Research Director of the National Great Rivers Research and Education Center in East Alton, Illinois. Currently, I am a Research Affiliate of the Illinois Natural History Survey, a unit of the University of Illinois at Urbana. My research specialty is big river ecosystems and the freshwater fish that use them. I have published 58 peer-reviewed articles related to these subjects, including 36 articles related to the Mississippi River and its tributaries. I previously directed the Large River Research Program of the Illinois Natural History Survey and the Water Resources Center at the University of Illinois at Urbana-Champaign. A major focus of my research has been the function of floodplains for Mississippi River system fish populations. I have served on three panels established by the National Research Council of the National Academy of Sciences. One panel focused on the Restoration of Aquatic Ecosystems, which included the Mississippi River and other large floodplain-river ecosystems. Its report discussed the importance of floodplains, and the potential value of floodplain restoration, and is directly relevant to the project at issue here. A second panel evaluated water resource planning policies and procedures of the U.S. Army Corps of Engineers. A third panel evaluated the potential for establishing a peer-review system for the U.S. Army Corps of Engineers. Because of these other panels, I am familiar with much of the Corps of Engineer's evaluation techniques and processes. A copy of my curriculum vitae is attached as Exhibit A.

I have reviewed substantial portions of the new draft Environmental Impact Statement. Previously I had reviewed substantial sections of earlier draft environmental impact statements and final environmental impact statements for this project. I have reviewed various Fish & Wildlife Service Fish & Wildlife Coordination Act reports, different variations of the fisheries analysis, mitigation analyses and other documents provided by the Corps. I have also reviewed two reports commenting on this project by Dr. Robert Sheehan filed with comments of Environmental Defense, as well as the report prepared by Dr. Sheehan under contract to the Corps of Engineers dated July 1998 entitled: St. Johns Basin and New Madrid Floodway Fisheries Survey: Final Report ("Sheehan 1998 Report"). I have also toured the project site and discussed the project with Dr. Paul Wills, who worked with Dr. Robert Sheehan, a fish biologist who was originally hired by the Corps of Engineers to analyze fisheries impacts of the project.

I have provided comments on early drafts and the previous final Environmental Impact Statement for this project. These comments go into substantial detail about why this project will have irremediable and harsh impacts on Mississippi River fisheries. The project is substantially unchanged since these earlier comments, with the main changes being that gates will not be closed and pumps activated until water levels reach very slightly higher elevations. These modest changes do not fundamentally alter my conclusions.

In fact, most of the proposed mitigation would now rely on forms of mitigation that earlier version of the DEIS recognized were problematic. Together, nearly all the fish mitigation (e.g., 90% during the mid-season), would be provided by Big Oak Tree State Park, batture land reforestation (land between the levies), and construction of artificial “floodplain lakes” (e.g., “ecologically designed borrow pits”). These forms of mitigation were considered in the earlier versions of the EIS but either rejected or greatly limited, and there is no new analysis to justify the changes in position. I summarize here:

New Mitigation	Previous Position	Comments below
Big Oak Tree State Park and Surrounding Reforestation	Earlier versions recognized that fish access to Big Oak and surrounding area was sufficiently problematic that it should not be counted for fish mitigation	Discussion below indicates that Big Oak and surrounding areas are at elevations at which gates must be closed before they are inundated, blocking fish access
Batture Lands	Although previous versions reserved the possibility of some use of batture lands, they recognized that mitigation in these lands had shortcomings.	Likely high velocities and low temperatures during flooding, as well as limited complexity of habitat mosaics, preclude uses of such sites for equivalent spawning and rearing habitat
Borrow pits and floodplain lakes	Corps agreed with interagency science committee that these habitats should only be used to offset impacts on other floodplain lakes.	New evaluation system accords even small areas of restored lakes inappropriately vast habitat value and habitat will be used to offset lost seasonal flooding of forests, agricultural land and other habitats

The new draft EIS continues to claim that these impacts on fish will be fully mitigated. In this statement, I explain why that is not the case: first, because the detrimental impacts of the project are underestimated; and second, the effects of mitigation are overestimated. There are several reasons for the problematic estimates, which I discuss below: (1) the closure of the New Madrid Floodway (hereafter, Floodway) will impede fish access to the floodplain to a degree not fully accounted for in the analyses of impacts and mitigation; (2) the impact analyses have additional problems; (3) the proposed mitigation is overvalued and often invalid; and (4) there are broader scientific flaws with the use of the fish model to analyze impacts and mitigation.

2. Fish Access

2.1 Importance of fish access to spawning and rearing sites on the floodplain.

A principal driving force for Mississippi River ecology was the annual flooding of a massive floodplain, which provided Mississippi River fish access to spawning and rearing grounds. According to estimates, 93% of this floodplain on the lower Mississippi River has been lost. That makes remaining habitats of this type extremely valuable. The combination of large contiguous areas, rapidly warming areas, diverse areas, productive areas, areas with slack water, and areas that meet all these conditions even in the largest

floods give the remaining open floodplain extraordinary value. The Floodway is one of the few large open floodplains that remain, and the only one remaining in Missouri.

For fish to take advantage of the Floodway for annual rearing and spawning, they must have access. One of the values of the New Madrid Floodway is that it provides an open quarter-mile gap for fish to access the Floodway. The project would greatly reduce that access by building a levee closure and gate. The impacts on access can be divided into two categories. First, even when the gates are open, fewer fish will move through the long dark, and narrow culverts than would move into the Floodway through an open river and floodplain. Second, the gates will often be *closed*, and they will be closed particularly during periods of expansive flooding. No fish will then move between the river and the floodplain. That is particularly important because most of the fish that access the Floodway only do so during their specific portions of the overall spawning and rearing periods; they seek to access the Floodway only at specific times when they need this function cued by such actions as certain water temperatures and rising water levels, and if the gates are closed at these times they cannot use the Floodway. In addition, not all fish will be prepared to move into the Floodway at the same time, and so closed gates during much of the spawning and rearing period will block fish access even if a few fish can gain entry at other times.

2.2 Fish access analysis ignores impact of closing the gates whenever extensive habitat would otherwise be available.

First, assuming no other problems with data or methodology, the fish access factor is calculated in a way that assumes the gates are open 100% of the time. In other words, it purports at best to calculate the impacts on fish access of replacing a quarter-mile-wide gap with four culverts. It does not address the issue that access will be blocked much of the time by closed gates.

The fish access factor calculation starts with a study for a single year that tagged a total of 85 fish, placed them below the St. Johns Bayou culverts, and determined how many of them moved through the culverts to the floodplain in the Bayou. Of all the tagged fish, 34% accessed the Bayou. In contrast, *all* (100%) tagged fish for the New Madrid Floodway entered that Floodway. Rather than using 34%, the Corps then determined that the floodplain gates were closed roughly one third of the time, and so adjusted the figure to 52%, on the theory that this percentage of the fish would have accessed the floodplain if the gates had been open the entire time. This point is critical. It means that the methodology is designed to estimate fish access assuming the gates are open all the time. This fish access figure does not account for the impacts on fish access of closing the gates. As a consequence, the impacts of the project on fish are underestimated, and the value of mitigation is overestimated, as described next.

The fish access factor is further increased to 73% based on an averaging of impacts on individuals and species. I discuss below why that incorrectly analyzes the fish access impacts even when gates are open.

2.3 Failure to account for lack of access results in underestimation of impacts.

For example, 1951 had flooding at 289 feet or above for nearly all of April, making it an excellent flood year for fish that spawn in mid-season, with access to more than 17,000 acres nearly that entire month. However, flood levels were above 286 feet on April 1st, so if the preferred alternative (3.1) had been in effect in 1951, the gates would have been closed the first day of the mid-spawning season, and those gates would have to have remained closed the entire month and until the middle of the first week of May. That means that for the bulk of the mid-season, there would have been no fish access. For the remaining ten days of the mid-season, the gates would have been open but water levels would have remained at 282 and 283 feet, flooding at most 1,764 acres. Thus, for a short term, fish might have had at least some chance of access but could use little habitat. Moreover, floodplain spawners usually move onto the floodplain with rising water levels, so with water levels receding rapidly during the relatively brief period when gates were open, there would probably be little movement into the floodplain. Overall, 1951 is a year that gate closure would have barred nearly all spawning or rearing use of the floodway during the middle of the spawning season although the Corps methodology would recognize the floodway as providing abundant habitat.

The year 1951 is not an anomaly. In many years in which there was flooding in the middle of the spawning season (1 April to 15 May), the gates would have been closed even before the mid-season started.

- For example, there was persistent flooding in 1952, but the gates would have been closed until the last few days of the mid-season, and only opened when water would be rapidly rushing from the Floodway.
- In a year like 1944, the gates would only be open for roughly half a week. Although flood levels in 1944 were high enough to have created large areas of habitat throughout the entire mid-season, the gates would have been closed most of the time.
- In a year like 1945, the gates would have been closed from April 1st until roughly May 10th and therefore only open for a few days in the mid-season and only when flood levels would be low.
- In a year like 1948, the gates would have been closed during an otherwise extensive habitat year from before the mid-season until nearly the end of the first week of May, virtually the entire fish spawning season. While the gates would have been open the final week, there would have been almost no habitat because the water would have receded.
- In a year like 1973 with extensive flooding throughout the entire mid-season, the gates would have been closed 100% of that mid-season.

These problems of fish access are at least as pronounced in the late season as for the mid season. The late season is a six-week period that extends from May 16th through June 30th. According to the gate closure rules, the gates must be closed above 284 feet in the last two weeks of May and at 278.5 feet in June (DEIS:Table 2.10, p48). At 278.5 feet, there could be no more than a few hundred acres of flooded habitat. Late season flooding is generally less extensive than during the mid-season. This rule means that throughout two thirds of the late season, the gates will never be open when there is more

than a trivial area of fish habitat, and they will rarely be open when there is extensive habitat even in the first two weeks. A year like 1974 would be an example where there was extensive flooded habitat throughout the entire late season without the project, but with the proposed project in place the gates would have been closed 100% of that year. Yet none of these impacts of gate closure are accounted for.

In summary, the impacts of the project are underestimated and the central issue remains just as Judge Robertson pronounced in his opinion: “[T]he need to keep the gates closed when water levels reach certain heights essentially guarantees that in years with habitat, there will be little or no fish access to the sump area during the mid-season; and in years with access, there will be little or no habitat.”. Opinion in *Environmental Defense et al. v. U.S. Army Corps of Engineers et al.*, Civil Action No. 04-1575 (D.D.C. September 13, 2007), p. 14.

2.4 Overestimation of fish access score even when the gates are open:

In addition to ignoring gate closure, the DEIS also overestimates the fish access when the gates are open. From its analysis of 85 individual fish, the Corps determined that 52% of the fish would access the floodplain if the gates were open year round. That 52% should therefore be the maximum fish access score for this period. However, the Corps also determined that for twelve of thirteen fish species examined, at least one individual accessed the floodplain. That implied to the Corps that 93% of fish species would access the floodplain (Appendix G Fisheries P. 37). The DEIS then uses that figure to increase the fish access score to 73% by taking the average of 93% and 52%.¹

This analysis makes no biological sense. If, as the Corps concludes, some species of fish will not make it into the Floodway if the project is built, that is a reason for further decreasing, not increasing the individual fish access score. I believe the loss of habitat for individual species entirely should count for a great deal, for reasons I discuss more below. But even if that only counted proportionately, the appropriate mathematical adjustment would be to reduce the fish access score by the percentage of species that would not make it into the Floodway, here 7%. That would make the fish access score when the gates are open 48%. Even this adjustment understates the significance of the fact that some species may not be able to access the floodplain at all through gates and culverts as operated according to the project plan.

¹ The access score of 52% was itself increased by averaging the actual ingress value of 34% (29 of 85 individual fish succeeded in moving through the culverts into the Bayou) with the egress value of 100% (all 11 fish placed upstream of the structure in the Bayou succeeded in exiting the Bayou through the culverts, according to page 37 of the Fisheries Appendix G). Ingress and egress should be separated because in the year the study was done, the direction of water flow through the culverts at the time the fish entered or left could have assisted some species. Also, it is important to know whether man-altered habitats are population sources or sinks. If more individuals of a species exit the habitat than entered, then the habitat is a population source. If more enter than exit, then the habitat is a population sink. My comments assume that the Corps used the 73% figure.

To see why it is invalid to average the percent species and the percent of individuals that accessed the floodplain to determine an access factor, I use a simple analysis. Imagine that only 1% of all individual fish were able to move through the gates when open, but that included 100% of all species. Under the approach now in the DEIS, the fish access score would be 50.5% even though the presence of the culverts would block 99% of all individual fish.

This failure to account properly for fish access problems leads to an underestimation of project impacts.

2.5. Failure to account for lack of access results in inadequate estimation of project impacts

According to the DEIS, even after the project is built, the Floodway will continue to provide 2082 annual aquatic habitat units (AAHU) in the early spawning season, compared to 3249 today, maintaining two thirds of its early season habitat value. For the mid spawning season, the comparable figures are 1668 AAHU compared to 3,279 under existing conditions, essentially half the present habitat value, and for the late spawning season, 884 of the 1811 present AAHU in the late season, also essentially half of its present habitat (49%). (These figures are all from Table III-3 of the Fisheries Appendix G, pp. 39-40.) If for no reason other than the enormous reductions in fish access, these figures are great underestimates of the reduction in fish habitat, as discussed next.

I here provide one alternative numerical estimate of the fish access problem. Dr. Amy Lerner, a geographer at Princeton University, used Corps-generated water level data (the data shown graphically in the hydraulics appendix), to calculate the percentage of days in each fish spawning and rearing season when (1) inundation would occur at or above 280 feet and (2) river gates would be open. For river gates to be open, inundation levels would have to be below 286 feet in March (the early season); below 286 feet from April 1st to April 15th and below 284 feet from April 16 through May 15th (the mid-season); below 284 feet from May 16th through May 30th and below 278.5 feet from June 1 through June 30th (the late season). We used 280 feet because only minimum habitat would be flooded below 280 feet, that is the lowest elevation for which the Corps provides data on habitat in the New Madrid Floodway, and even if fish could access areas below 280 feet, they would find minimal habitat. It is important to recognize that once the gates are closed, fish lack access not only to areas above these elevation levels (e.g., 286, 284 and 287.5 feet, depending on the spawning season) but to habitat below these elevation levels as the gates are located and closed far below 280 feet. Lerner's analysis using the R statistical program is that the gates would be open when water levels are above 280 feet only 45.5% of the early season; 32% of the mid-season and 14% of the late season. Over the entire three seasons, the gates would be open 32% of the days that water levels are above 280 feet.

The figure of 32% still significantly and generously overstates fish access for two reasons. First, it treats a day of fish access when water levels are merely at 280 feet, when only 519 acres would be flooded, as equivalent to a day of fish access when water levels are at or above 286 feet, when at least 5,282 acres would be flooded. Many of the

days when gates would be open and water levels are above 280 feet are days when elevations are much closer to 280 feet. Second, many of the days gates are open with water levels above 280 feet occur at the end of each fish spawning or rearing season when levels are receding from higher elevations. Fish could only then access the floodplain if they fought against the currents and if so, only for a handful of days while the habitat remained flooded. The assumption of potential fish access in these open gate days is therefore generous.

A composite fish access factor would therefore be the percentage of days with gates open (32%) multiplied by the fish access factor for when gates are open, which we indicate above should be 48% if one relied on the Corps data, for a composite fish access factor of 15% (32% multiplied by 48%).

If one applies this more accurate, but still generous, fish access factor to the habitat the DEIS claims will remain in the New Madrid Floodway, the additional loss of habitat is as follows

Fish Spawning and Rearing Season	Claimed AAHU With 73% Fish Access Factor (Table III-3 Appendix G)	AAHU With Adjusted 15% Fish Access Factor	Additional Losses
Early	2081.54	437	1645
Mid	1668.04	350	1318
Late	883.65	186	698

I wish to emphasize again that the use of the 15% access factor is generous for the reasons noted above.

2.6 Failure to account for lack of access results in large overestimates of project mitigation.

The lack of fish access also leads to gross overestimates of the value of fish mitigation. I address different components of that mitigation below.

Big Oak Tree State Park. Efforts to regenerate roughly 1,800 acres of forest and to maintain water levels higher in Big Oak Tree State Park by building levees around it have been part of the mitigation plan for at a least the last two final and draft versions of the DEIS. In all these versions, the Corps neglected to claim fish mitigation credit for the Park because it recognized the difficulty of fish access. In this DEIS, there is no explanation of how these technical problems would be overcome, but the DEIS claims the same fish access as for the remainder of the New Madrid Floodway. As shown in Table 23 of the Fisheries Appendix G reproduced below, when combined with the claimed increase in flooding, Big Oak Tree would provide 914 AAHU in the early season out of 1729.5 needed; 889.5 out of 2061.1 needed in the mid-season, and 577.3 out of 1,165.8 needed in the late season. Big Oak Tree Park therefore provides a majority of needed mitigation in the early and late seasons and 43% of mid-season mitigation.

Table 23. Fisheries compensatory mitigation benefits (AAHU) in the St. Johns Bayou Basin.

Mitigation	Acres	Early	Mid	Late
Impacts		-386.6	-441.3	-245.3
BLH Restoration < 285'	400	40.7	41.9	15.4
BLH Restoration < 5-year	1,816	124.2	127.9	50.1
Riparian Buffer Strips	47	5.9	5.6	1.8
Ecologically Designed Borrow Pits	387	268.4	268.4	268.4
Net Gain		52.6	2.5	90.4

Table 24. Fisheries compensatory mitigation benefits (AAHU) in the New Madrid Floodway.

Mitigation	Acres	Early	Mid	Late
Impacts		-1,729.5	-2,061.1	-1,165.8
Big Oak Tree State Park and Surrounding Area	2,800	914.0	889.5	577.3
BLH Restoration < 285'	387	61.7	70.5	0.0
BLH Restoration < 5-year	1,970	179.3	84.7	0.0
Batture Land Reforestation	3,050	692.4	692.4	310.2
Ecologically Designed Borrow Pits	60	41.6	41.6	41.6
Floodplain Lake	432	326.8	326.8	326.8
Net Gain		486.2	44.4	90.1

The above Tables are from Mitigation Technical Appendix R, p. 40.

The proposed mitigation includes an additional gate and canal to get water directly to Big Oak Tree State Park from the Mississippi River to the south. However, it does not propose to build large levees to line that canal. As a result, to prevent water from overflowing into the surrounding lands, the gates to that canal will also have to be closed according to the same flooding elevation schedule as the principal gates to the New Madrid Floodway.

According to information in the Big Oak Tree State Park Natural Resource Management plan provided by the U.S. Fish & Wildlife Service, land in the Park is between elevation 290 and 292. These elevations are above those at which the New Madrid gates must be closed throughout the entire fish spawning season, which are 288 feet in March, 286 feet in the first two weeks of April, 284 feet from April 16th through June 1st, and 278.5 feet in June. These elevations mean that the gates will be closed 100% of the time that water levels are high enough to reach Big Oak Tree State Park.

In addition to Big Oak Tree itself, the mitigation plans 1,800 acres of reforestation around the Park. But according to the DEIS, these potential lands range in elevation from 285 to 295 feet. In other words, nearly all of this land is above the 286 gate closure level that is the highest level in both the early and mid-season, and all is above the 284 foot level that is the highest gate closure level for the last four weeks of the mid-season and all of the late-season. The only time in the mid-season that the gates would be open and flooding could occur in the absolute lowest of these lands are the few days when water levels are at or above 285 feet, but below 286 feet. Even if fish accessed these restoration lands at that time, once the gates were closed at 286 feet, no more water could enter the Park and the only habitat available would be only that small portion of the restoration sites roughly at 286 feet. The land in the Park is above 290 feet and would be unavailable to fish at a water elevation below 286 feet.

There would be even further problems in getting fish to Big Oak Tree State Park. At a very minimum, no water could be allowed into the Park from the river during the fish spawning and rearing seasons without flooding adjacent lands. However, the plan somewhat vaguely calls for maintaining water levels longer in the Park than at present. To do so, a set of secondary gates to the Park would have to be closed to keep the water in. That would prevent a further impediment to fish access even if the gates to the Floodway were open.

More broadly, I cannot understand how the Corps expects ever to get water to the Park from the river. According to the DEIS, gate closure is supposed to occur even outside the fish spawning and rearing season at 288.5. That would only allow water to enter the Park from the river up to that elevation. Higher water levels in the Park would have to result from interior rainfall. That may occur, and in fact, the primary “benefit” for extended flooding of the water control system is likely to be from this interior rainfall (or possibly if the Corps later decides to add pumps). But that source of water would not permit fish access.

The DEIS claims that there would be fish access because “water would be flowing into the basin during many open-gate periods,” p. 176, but those periods would be outside of the fish spawning and rearing seasons. It is not plausible to conclude from this overview that Big Oak Tree will provide anything more than negligible spawning and rearing habitat if any.

Five-year Forest Restoration Lands . The DEIS also proposes to reforest 1,970 acres of forest below the five-year flood elevation line post-project. According to page C-6 of the hydraulics appendix, that would be 288.7 feet in the New Madrid Floodway. That is distinguished from the two-year flood elevation line of 287.6 feet and other lands that the DEIS proposes to reforest at 285 feet. Presumably therefore, these lands will be all or at least predominantly above 285 feet and up to 288.7 feet. Again, according to the DEIS, the gates will never be open when any lands above 286 feet will be flooded during any part of the spawning and rearing season. Even if some lands are between 285 and 286 feet, they will never be flooded for two thirds of the mid-season and all of the late season;

and they would only have fish access in those extremely few days when flood levels were over 285 feet but below 286 feet. In short, these lands will have little to no fish access.

285 Foot Elevation Forest. The mitigation would include 387 acres of forest restoration at 285 foot elevation. Again, fish would face closed gates whenever habitat enhanced at this elevation would be flooded during two thirds of the mid-season and all of the late season, and would only be able to access this habitat during the early season and first third of the mid-season during the few days when inundation levels are between 285 feet and 286 feet.

In short, the DEIS relies heavily for mitigation on reforestation and other changes within the New Madrid Floodway, but these sites will be located at 285 feet at the lowest elevation and generally higher. Although project areas below 285 feet might have some reduced fish access if the project is built, these mitigation sites would have almost no fish access when flooding is actually occurring during the spawning and rearing seasons. The only mitigation sites that would not have these fish access barriers are those in the batture lands. I explain later why those mitigation sites are inappropriate for separate reasons.

2.7 Scientific limitations of fish access analysis even in open-gate periods

All of the above discussion takes at face value the adequacy of the scientific analysis of the extent to which fish will move through open culverts. In fact, for several reasons, these analyses do not meaningfully establish the claims that 52% of fish will make it through open culverts.

- First, nearly all the fish studied were mid-season fish. No early season fish were studied, and only one late-season fish was studied during the late season (channel catfish, Table II-1 p. 20 Fisheries Appendix).
- Second, the tracking of individual fish occurred only one year, with a small number of fish, and a restricted number of species. There were 32 smallmouth buffalo, 14 bigmouth buffalo and 18 white bass tagged, but only 1 to 7 individuals of 11 other species were tagged. (Table II-1 p 20 Fisheries Appendix).

The limited number of species analyzed is particularly concerning because fish behaviors are very different and all of the species analyzed were large-bodied fishes, presumably because of the problems of putting transmitters on small fishes. The extremely limited sampling simply cannot establish the degree of fish access claimed.

In addition, data gathered by Robert Sheehan suggests that the 7% reduction in species access is too low. In sampling done in both basins by Dr. Sheehan for the Corps, he found young-of-the- year fish from only 11 species in the St. Johns basin compared to 24 different fish species in the New Madrid basin. The fact that St. Johns also has local stream fishes implies that even that figure probably underestimates the number of species coming through the river gates.

This insufficient understanding of how many fish will enter the Floodway when gates are open has important implications. First, assuming that authorization of the project

requires an affirmative judgment that mitigation fully offsets project impacts, insufficient evidence makes such a judgment unjustified. Second and more fundamentally, the science of analyzing impacts and mitigation is based on the understanding that much remains poorly understood of the complex combination of attributes of aquatic ecosystems that fish and other species rely upon. As a result, the science has recognized the importance of maintaining natural hydrological processes and complexity, and an obviously important hydrologic factor is open fish access. The scientific principles that have emerged therefore emphasize the maintenance of these factors.²

2.8 A Possible Major Conceptual Error

If this project is not built, the habitat available in the New Madrid Floodway will continue to be accessible to river fish during floods. The impact of the project, under the logic of the fish model, would therefore start with total fish habitat units under existing hydrologic conditions. It would then subtract the habitat under proposed Alternative 3.1, which would be calculated as the inundated habitat available (average annual habitat units for each season) multiplied by the fish access factor (73%). The difference is the loss of accessible fish habitat attributable to the project, which should be mitigated.

On page 32 of the Appendix G Fisheries, the Corps states that project impacts were calculated assuming that “future without project” conditions were also reduced through multiplication of the “fish access reduction.”³ That would be an obvious mistake. Taking this language at face value indicates that the Corps improperly reduced its estimation of the project fish habitat available without the project by 27%. That would in turn mean that fish impacts were underestimated as follows: early season (877 AAHU); mid-season 885 AAHU, and late season by 489 AAHU.⁴ These underestimates would add roughly 50% to the estimation of project impacts through correction of this error

² There may be another problem with the fish analysis if, as the DEIS fish appendix states, the Corps applied the fish reduction factor not just to the proposed project alternative but also to the evaluation of habitat in existing conditions. On page 32 of the Appendix G Fisheries, the Corps states that project impacts were calculated assuming that “future without project” conditions were also reduced through multiplication of the “fish access reduction.” That would be an obvious mistake. Taking this language at face value indicates that the Corps improperly reduced its estimation of the project fish habitat available without the project by 27%. That would in turn mean that fish impacts were underestimated as follows: early season (877 AAHU); mid-season 885 AAHU, and late season by 489 AAHU. These underestimates would add roughly 50% to the estimation of project impacts through correction of this error alone. My hope is that the Corps did not make this obvious error, but that instead, it was an error in the description of the methodology on page 32.

³ The following is a cut and paste from the document:

Project impacts were calculated by the following formula:

$$\text{Project Impacts} = (\text{AAHU Future Without Project} \times \text{Fish Access Reduction}) \\ - (\text{AAHU Future With Project} \times \text{Fish Access Reduction})$$

alone. My hope is that the Corps did not make this obvious error, but that instead, it was an error in the description of the methodology on page 32.

3. Additional Problems with Impact Analysis

The DEIS understates the project impacts on habitat area and value because it excludes important habitat areas for invalid reasons and undervalues flooded agricultural land. It also underestimates impacts on floodplain lakes.

3.1 Exclusions of habitat areas

The fish habitat evaluation technique uses a variety of exclusions to ignore and to diminish valuable habitats. First, the technique excludes 100% of flooded agricultural land above the two-year floodplain. This exclusion ignores tens of thousands of acres of flooded habitat. Second, even for agricultural lands below the two-year floodplain, the habitat is ignored if they are flooded for less than a depth of one foot and for less than eight consecutive days. (The DEIS is somewhat ambiguous, but some of the language suggests that these hydrologic criteria were also applied to flooded forests and marshes.) Third, all areas above the five-year floodplain are ignored completely. These exclusions are inappropriate and the exclusions of agricultural land are illogical even under the terms of the rationale expressed in the DEIS.

I first address the exclusion of agricultural lands below the two-year floodplain unless they are flooded eight consecutive days and to a depth of one foot. That exclusion is essentially justified by spawning criteria. The theory is that eggs laid in shallower, less frequently flooded water will dry up. Even if true, these criteria do not define rearing habitat. Fish can and do move into and out of flooded areas as floodwaters move up and down regardless of whether they are flooded for eight consecutive days. Shallow water areas are also used by rearing fish. The DEIS even acknowledges that, stating: “Once hatched, rearing fish . . . can potentially use any area of the inundated floodplain regardless of flood depth and duration.” Fisheries Appendix p. 34 (emphasis added). For that reason, the DEIS accepts that forested habitat will be counted if it is flooded on any day it is flooded to a depth even of one tenth of a foot. Flooded agricultural lands also provide rearing habitat. There is no justification for the differential treatment of flooded agricultural lands and flooded forest for rearing purposes.

The value of shallow water habitat was emphasized by Dr. Sheehan based on his sampling. In comments on this project, he wrote:

“Our evidence, collected using an active sampling gear (seining) . . . shows that small fish prefer habitats less than one foot in depth (probably to avoid predation by larger fish) as opposed to deeper depths, even when cover type stays the same. Using seining, we collected a total of 2,572 fish in seine samples from the shallowest water along the shore in Mississippi River waters of 1 foot or less, whereas we captured only totals of 407 and 206 fish in comparable sampling done at progressively deeper depths. We have found 39 Mississippi River species use waters of one (or less) foot

depth. Much of our sampling was done in the spring. We find elevated water temperatures in the shallow, near shore area, perhaps explaining why they are used as much as they are by small fish."

Another justification for excluding more temporarily flooded lands is that they may dry up and leave fish stranded. Again that theory would apply equally to forest and agricultural lands and not justify differential treatment. More fundamentally, strandings of small fish have ecological value. Rearing fish are valued not merely because they contribute to the fish population but also because they provide food for migrating birds and other wildlife, which they can provide when stranded. This rationale is an example of how the focus on individual wildlife categories leads to flaws in evaluating impacts on the broader ecology.

The justification for excluding lands above the two-year floodplain is that they are on higher ground than the 1-to-2-year elevations and therefore farther from the downstream access point to the river. The assumption is that the farther the habitat is from the access point, the less likely that migrants from the river are to use it (Fisheries Appendix p 34). There are two problems with this claim. Again, even if true, that would not provide a justification for ignoring agricultural lands but counting forested lands, as both would be too far removed. More fundamentally, it is not true. Figures 1.4 and 1.5 indicate that land elevations are patchy, not neatly zoned by distance from the downstream access. Patches of 5-year floodplain occur adjacent to 2-yr floodplain at equivalent distances from the access. The DEIS provides no evidence for the claim that fish do not access these areas. Again, Dr. Sheehan, who actually sampled the fish habitat in these areas for the Corps, strongly disagreed with this exclusion.

Put simply, any reduced value for agricultural habitat can logically at most justify the lower habitat score for each acre when flooded. It cannot justify different hydrologic criteria. Rearing fish will move into and out of shallow waters that are only flooded for a day and only flooded to a few inches.

Finally, I can see no justification for exclusion of habitat above the five-year floodplain. Many fish that use the project area live for ten years or more, even decades. They can take advantage of even occasional floods to boost their populations—a boost that may last for years. Even fish that live shorter periods of time gain boosts in their populations. And those small fish are in turn consumed by long-lived larger fish and by birds and other species that have long life spans. The greater food supply boosts the nutrition and reproductive capability of the adult consumers and the growth and survival of their young. Also important, these areas provide increased habitat during high flood periods when any spawning and rearing available in the batture land will be even more reduced because of the high velocities. In other words in high flow years they not only supplement habitat available at lower elevations, they may be needed to substitute for those lower elevation habitats, which become less available. The hydrologic criteria used by the Corps inherently values habitat based on its frequency and duration of flooding, and the hydrologic model provides the means of doing so. There is no justification for

excluding categories of habitat within the project area up to the maximum area of backwater flooding.

3.2 Undervaluation of agricultural land

Flooded agricultural lands can have high values even for spawning. Species such as the sunfishes and basses can find firm substrates on fallow and farm ground on which to construct their nests. Elsewhere, in the permanent water bodies and channels, particularly those in the Floodway, there are accumulated soft sediments that are poor nesting substrate, according to the DEIS. A similar situation exists along the Illinois River, where I have observed basses and sunfishes nesting on gravel roads and fallow and farmed land during floods. Floods, including the 3-to-5-year floods, provide access to these firmer substrates.

When any floodplain lands are flooded, even agricultural lands, plankton blooms appear following release of nutrients from the flooded soil. Those food supplies attract small fish as Dr. Sheehan found, and do so whether lands are agricultural or not. The plankton can be carried by floodwaters into other habitats, providing important food supplies.

There is no real evidence provided by the DEIS for the extremely low habitat value assigned to flooded agricultural land. It may be lower in general, but will vary for different fish and all fish should be considered important. Greater true evidence should be necessary before so dramatically underestimating the value of habitat we know to be used and to supply food supplies to adjacent areas.

3.3 Underestimation of impacts on floodplain lakes

Floodplain lakes can have high fish values, but their value for river fish is largely based on their value as refugia for young fish otherwise bred in the floodplain that allows them to grow and that gives them increased chance of survival if they exit during a subsequent flood. For floodplain lakes to have this value, they need to be embedded in a larger flooded floodplain and there needs to be abundant opportunity for ingress and egress by river fish. (Floodplain lakes closer to the river may also have values even if not embedded in a larger floodplain, but less for spawning and rearing of floodplain-dependent fish.)

In prior analyses, the project estimated impacts on floodplain lakes by estimating the reduction in the period flooded by the river. The value of the lakes was based on how often they were flooded within each fish spawning season. As a result, if river flooding declined from 30% to 10%, lake value declined by 20%. That was an imperfect system (and of course ignored fish access problems) but it had at least focused on the importance of flooding between the river and the lakes to establish value for spawning and rearing habitat.

The new evaluation technique overvalues floodplain lakes relative to other floodplain habitats and at the same time greatly underestimate the impacts on floodplain lake habitat.

The new technique overvalues floodplain lake habitat by assigning it a value that is the equivalent to flooding of a bottomland hardwood for 100% of the days in all years and in all seasons. It does so by giving these lakes the same habitat unit score as flooded forest, but then assigning it the equivalent value of 100% ADFAs (average daily flooded acres), i.e., by assuming these habitats are available every single day of every single year. The permanent lakes are indeed wet all year round but they are not “flooded” by the river for that period.

The implications can be seen in Tables III-1 and III-3 of the Fisheries Appendix. As noted above, the spawning and rearing value of 640 acres of floodplain lakes in the New Madrid Floodway are considered equivalent to the value of roughly 7,995 acres of flooded forest within the five-year floodplain for the late season and more or less half the value of those forests during the early and mid-seasons.⁵ They are always considered of more value than all the area’s tens of thousands of acres of flooded agricultural lands. The overvaluation in the St. John’s basin is similar.

On the other hand, the impacts on this habitat are heavily underestimated because the assumption is that any floodplain lakes flooded once every five years at any time of the year, for any duration retain their full value spawning and rearing habitats. The result is that floodplain lakes in the New Madrid Floodway only decline from 728 AAHU (average annual habitat units) in each season to 653 AAHU in each season for Alternative 3.1. Table III-3.

I can use the late season to show the error of this view. According to Table 21 of the Mitigation Appendix, under the proposed project (Alternative 3.1), water levels during the late season will never reach an elevation of 285 or higher (and areas at 284 feet will be flooded by the river less than 1% of the time). That means that 576 acres of floodplain lakes counted by the project as continuing to provide 100% ADFA habitat for a huge habitat score will never actually be flooded from the river in the late season and therefore could not provide fish spawning and rearing habitat for late season fish.⁶

⁵ According to Table 3.2 of the DEIS, there are 689 acres of permanent water bodies in the New Madrid Floodway up to 297 feet (rounded from 296.6), the 5-year floodplain. According to Table III-3 of the Fish Appendix, they are treated as providing 728.47 average daily flooded acres, and therefore 728.47 average annual habitat units for each spawning season: early, middle, and late. (That may be because assumptions of additional WRP lands bring water bodies up from 689 to 728.47.) According to Table III-3, bottomland hardwoods provide 733.53 average annual habitat units, roughly the same. They are based on lands flooded up to the five-year floodplain, which is 297 feet of elevation, and according to Table 3.2 of the DEIS, these habitat units are created by 7,995 acres of forest. Table III-3 also indicates that this same acreage of flooded forest (bottomland hardwoods) provide 1,629 average annual habitat units during the mid-season, which is more than twice the 728 units provided by permanent water bodies.

⁶ According to Table 3.2 of the DEIS, there are 727 acres of floodplain lakes at or under 294 feet, the five-year floodplain. There are only 151.5 acres of such lakes at the 284 foot flood elevation, a difference of 488.5 acres. The Corps found a decline of floodplain lake habitat of 75 acres.

This approach leads to only an extremely small estimation of impacts on open water habitat and a very high estimation of potential benefits from a small area of open water mitigation.

The proper way to evaluate impacts on floodplain lakes is to treat them as an important habitat but one that is fundamentally distinct from other floodplain habitats. That was implicit in previous versions of the EIS where the Corps concurred with the Fish & Wildlife Service that lake habitat would be mitigated separately by other lake habitat.

Instead of assuming that these lakes retain their value for spawning and rearing habitat if they are flooded at any time during the five-year floodplain, their value should be tied to their frequency of flooding and to their associations with broader floodplain habitat. Different arguments could be made about how to do so. At a minimum, these 576 acres of floodplain lakes above 284 feet should be recognized as losing their fish spawning and rearing habitat.

More generally, the combination of substantially reduced flooding on the lakes, plus the restrictions on fish access, plus the loss of broader floodplain habitat should lead to the general judgment that the value for spawning and rearing of these lakes in the New Madrid Floodway are lost. Appropriate mitigation for the lakes alone could, in theory, occur by restoring lakes in the context of a broader restoration of inundation to a comparable backwater habitat.

4. Proposed Mitigation is Overvalued and Often Invalid

Much of the mitigation proposed would be behind levees in the floodplain, including Big Oak Tree State Park work, which would be behind two sets of levees, and is overvalued because of the limitations of fish access.

The second principal source of mitigation is supposed to occur through reforestation of batture lands, i.e., lands between the main channel of the Mississippi River and the main levee. These lands would not have fish access problems but would rarely provide equivalent rearing and spawning habitat for two principal reasons: First, the great bulk of batture lands, and perhaps all, will have substantially colder water than backwaters because of their continual replenishment with water from the river that is, on average, deeper and comes from the north. As both Robert Sheehan and I have previously written in comments on this project, temperature is an important component of the value of floodplain habitat and warmer temperatures are essential to successful spawning and rearing.

Second, batture lands will all or nearly all have more rapidly flowing water, particularly during high floods. Most batture lands closely hug the river. The Corps has indicated previously that

Deducting the 75 from the 488.5 still leaves more than 400 acres considered to provide 100% habitat in the late season although never flooded in the late season.

even wider floodplain areas in the batture, such as Donaldson Point, experience rapidly flowing water during high flood years.

There is a mathematical error in the estimation of fish mitigation for reforesting 387 acres below 285 feet in elevation on page 31 of the Mitigation Appendix.⁷ According to the equations and logic presented, the habitat provided by the reforested land should be based on the Mid-season AAHU of 60.1. That figure should be multiplied by the fish access factor of .73, to generate a mitigation figure of 43.9 rather than 81. With the subtraction of existing habitat value of 10.5, the net gain is 32.4. The error was the substitution of the figure 110.9 in the parentheses of the fish access coefficient rather than 60.1 on the line above. The result is an overstatement of mitigation benefits by 38.1 AAHU.

The Corps proposed to achieve much of its mitigation through the creation of open water bodies. This mitigation would compensate not merely for loss of other open water body habitat but floodplain forests and agricultural lands. For the reasons I explained above, this type of habitat is greatly overvalued.

One of the sites the Corps would “restore” as a lake is Riley Lake. This area already floods frequently, contains 180 acres of trees, and is valuable habitat. The Corps claims that it would generate roughly 327 AAHU in every season by building a levee around Riley Lake up to an elevation of around 287 feet, turning it into a pond. Not only would that overvalue the habitat value for reasons discussed above, but the levee would actually significantly reduce fish access to areas that can now be accessed far more frequently and extensively.

More broadly, the ecologically designed borrow pits and the modified water bodies are likely to fill more rapidly with sediment in the batture than in many of the backwater areas within the Floodway and the Bayou. The main current of the Mississippi carries high sediment loads, especially during floods, and the closer the water bodies are to the channel, the more quickly they will accumulate sediment, unless they have high current velocities that keep sediments in suspension. By contrast, as the name “backwater” indicates, the water backs relatively slowly into the lower portion of the New Madrid Floodway during seasonal floods, allowing river sediments to drop out in areas nearest the river. Although sedimentation occurs and some habitat maintenance is therefore required in the backwater areas, the rates of sedimentation and costs of maintenance are likely to be less than in the batture adjacent to the main channel, except in areas

⁷ The calculation is at page 31 of the mitigation appendix.

The following steps were used to determine compensatory mitigation benefits in the New Madrid Floodway from reforesting 387 acres¹³ (approximately 25 percent of available farmlands) of agricultural lands below an elevation of 285 feet in the mid-season period:

BLH Transition: $859.2 \text{ HU} = (20 \text{ years}) * (71.6) * [(0.2+1.0)/2]$

BLH for remainder of project life: $= 2,148 \text{ HU} (30 \text{ years}) * (71.6) * [1.0]$

Cumulative HU: $3,007.2 (859.2 \text{ HU} + 2,148 \text{ HU})$

Mid-Season AAHU: $60.1 (3,007.2 \text{ cumulative HU}/50 \text{ years})$

Fish Access Coefficient: $81.0 (110.9 * 0.73)$

Mitigation Benefit = 70.5 AAHU $(81.0 \text{ with mitigation AAHU} - 10.5 \text{ without mitigation AAHU})$

where scouring velocities occur during advance and recession of floods. Scouring velocities would preclude spawning and rearing by fishes that access the floodplain to reproduce and rear their young.

This review indicates that all of the proposed mitigation sites offer limited potential mitigation for fish. Reforestation of areas within the floodplain will provide areas with extremely limited access by fish. Reforestation of batture lands is unlikely to provide habitat of equivalent value for spawning and rearing because of the high velocities and low temperatures. Digging of open water areas in the batture lands is likely to create habitat that will be rapidly silted in, and the changes to Riley Lake proposed are adverse: reducing fish access to already existing habitat.

5. Scientific Shortcomings of the Impact and Mitigation Analysis

In all of the above comments, I have largely taken the concept behind the fish model at face value, focusing on its detail. For reasons I, Dr. Sheehan, the Fish & Wildlife Service and others have consistently emphasized, this whole type of analysis is fundamentally unscientific because it treats each acre as though its value is independent of its relationship to other acres, and as though it depends entirely on only two factors: flooding and basic vegetation cover. It is well-known instead that the value of aquatic habitat depends on many more physical characteristics including flow and temperature and rates of change, and just as importantly on its landscape position. Landscape factors include whether the acre is part of a mix of other habitat types on which its value depends; whether it is part of a large contiguous area of habitat; and whether it is rare.

The project area's value is based on the fact that even though manipulated it provides a large, relatively naturally flooded, contiguous, complex and connected form of habitat to the Mississippi River. This type of habitat is extremely rare. It simply cannot be replaced by the piecemeal manipulation of other small areas, particularly in different landscape locations, with different connectivity and without the same mosaic of habitat types. It certainly cannot be replaced by a much smaller area simply because of these manipulations.

Robert Sheehan made this point in an earlier report: “[T]he Mississippi River used to have access to an extensive floodplain characterized by a range of backwater ponds and wetlands, stream networks, and combinations of cover type. Different fish prefer different kinds of habitats, and the same fish prefer different habitats at different stages of their life cycle and even during different times of the day. As floodwaters recede, an extensive stream (or even ditch) network provides a valuable resource for fish to recede through. It is the mosaic of habitat types provided in the project area that is ecologically valuable.”

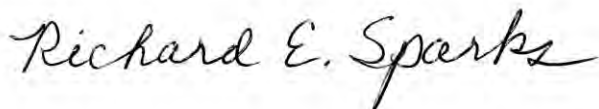
As I have previously noted, the Corps fishery biologist Dr. Kilgore admitted many of these important characteristics for fish habitat in a deposition that are not incorporated into the fish model. These characteristics he agrees include slack water; water that

warms relatively early; and a mosaic of flooded lands and permanently wet streams and ponds. These are all important characteristics of the project site, but the mitigation plan does not require or even contemplate that they be reproduced in the mitigation sites let alone as a mosaic.

It is also important to recognize that even to the extent the fish model represents the best scientific judgments of some about such things as preferred habitat values, it is based on little evidence. There are dozens of fish species in the Mississippi, and as Dr. Sheehan noted, they have different needs at different stages of their lives and rely on areas to provide food (such as plankton) that they may not reach themselves. With the possible exception of sport fishes, relatively little documentation exists on the requirements of many of these species. For example, one habitat score, e.g. 0.2 for agricultural land, is inappropriately provided for *all* fish, and that score is based largely on guesswork.

Recognizing these limitations and complexities, ecologists have instead focused on what they do know: which is that certain characteristics are important: including spatial extent, natural hydrologic patterns, contiguity, complexity and connectivity. The fishery analysis mostly ignores these factors that are important, and the mitigation plan pays them no attention at all. Instead, fish habitat is based entirely on the vegetation cover of the land and on the average duration of flooding during three seasons.

I conclude by quoting the accepted understanding expressed in 1992 in a report by the National Academy of Sciences: “Restoration of the flow regime is one of the most neglected aspects of stream and river restoration ... Preservation of a river channel is not sufficient to ensure survival of fish that spawn on floodplains—both the floodplain and the flood cycle must be maintained (NRC 1992:180). It further states (page 175): “Immediate attention should be given to the remnants of large river-floodplain systems that still exist, because there are so few (e.g., there is only one twelfth-order river in the conterminous United States, the Mississippi River).

A handwritten signature in black ink that reads "Richard E. Sparks". The signature is written in a cursive, flowing style.

Richard E. Sparks, Ph.D.

Appendix A. Short Resume Dr. RICHARD E. SPARKS
(updated 24 November 2013)

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Dr. Richard Sparks is an aquatic ecologist currently affiliated with the Illinois State Natural History Survey, a unit of the University of Illinois at Urbana-Champaign. He formerly directed the Illinois Water Resources Center at the University of Illinois. In 2002 he helped found the National Great Rivers Research and Education Center on the Mississippi River at Alton, Illinois. The Great Rivers Center is a partnership between the University of Illinois and Lewis and Clark Community College. For 26 years he directed the Large River Research Program of the Illinois Natural Survey from field stations located on the Illinois and Mississippi rivers. He has authored or co-authored 211 articles, book chapters, reviews and reports, including The Flood Pulse Concept in River-Floodplain Systems, a much-cited paper which describes the role of seasonal flood cycles in maintaining the ecological structure and function of large floodplain-river ecosystems. He has served on several committees of the National Research Council, most recently the Committee on [Improving Principles and Guidelines for Federal Water Resources Planning](#), which advised the Obama Administration's Council on Environmental Quality. From 1995 to 1997 he served on the Illinois River Strategy Team and the Hydrology and Hydraulics Action Team for the Integrated Management Plan for the Illinois River Watershed. In Argentina, Brazil, India, and China he provided advice on management of floodplain ecosystems and large rivers. He served on the Illinois Long-Term Flood Recovery Council, which was funded by the U.S. Economic Development Administration to help Illinois develop a flood recovery strategy, following the floods of 2008.

EDUCATION:

Post-doctoral Research Associate 1972, Center for Environmental Studies, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Research: Rapid assessment of water quality, using aquatic organisms as sensors (funded by U.S. Environmental Protection Agency).

Ph.D. Biology 1971, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
Doctoral dissertation: Using the respiratory responses of bluegill sunfish (*Lepomis macrochirus* Rafinesque) to monitor zinc concentrations in water. (funded by U.S. Environmental Protection Agency)

M.S. Zoology 1968, University of Kansas, Lawrence, Kansas

M.S. thesis: Effects of treated effluent from the Sunflower Army Ammunition Plant on fish. (funded by the Kansas Biological Survey)

B.A. Biology 1964, Amherst College, Amherst, Massachusetts

PEACE CORPS SERVICE: Nigeria, 1964-1966

CURRENT POSITION:

Research Affiliate, Illinois Natural History Survey, a division of the Prairie Institute at the University of Illinois at Urbana-Champaign

PROFESSIONAL ACTIVITIES (selected from last 5 years):

Current: Science advisory committees: American Rivers; the following units of The Nature Conservancy—Illinois Chapter; the Great Rivers Partnership; the Emiquon Floodplain Restoration Project.

2010-2011 Member of National Research Council Committee (U.S. National Academy of Sciences and National Academy of Engineering) to review the Principles & Guidelines for Planning Water Projects. P&G establishes objectives and procedures for planning water resources projects undertaken by several federal agencies, including the Corps of Engineers, Bureau of Reclamation, Department of Agriculture, and others.

2008-2009 The Illinois Long-Term Flood Recovery Council.

CONTRIBUTIONS TO SCIENCE EDUCATION: Firth, Penny, Richard E. Sparks, and Milton Muldrow, Jr. Units on River and Water Science for elementary school teachers and students: see <http://www.sciencenetlinks.com/lessons.php?BenchmarkID=11&DocID=523>

SELECTED PUBLICATIONS (From a total of 211 papers, including refereed journal articles, book chapters, symposium proceedings, and reports. Publications are arranged by subject category and in order from most recent to oldest.) Some publications are listed in more than one subject category.

Policy: invasive species; water science and long-term studies; management, restoration, & naturalization of aquatic ecosystems

- Rasmussen, Jerry L., Henry A. Regier, **Richard E. Sparks**, and William W. Taylor. 2013. Aquatic invasive species risks to the Great Lakes and Mississippi River Basins: Asian carp as a case for serious consideration of hydrologic separation. Pages 767-786 in William W. Taylor, Abigail J. Lynch, and Nancy J. Leonard, editors. *Great Lakes Fishery Policy and Management: A Binational Perspective*. 2nd Edition. 2013. Michigan State University Press, East Lansing, MI.
- Rasmussen, Jerry L., Henry A. Regier, **Richard E. Sparks**, and William W. Taylor. 2011. Dividing the waters: The case for hydrologic separation of the North American Great Lakes and Mississippi River Basins. *Journal of Great Lakes Research* 37(3):588-592.
- Sparks, R.E.** 2010. Forty years of science and management on the Upper Mississippi River: an analysis of the past and a view of the future. *Hydrobiologia* 640:3-15.
- Sparks, R.** 2006. Rethinking, then rebuilding New Orleans. *Issues in Science and Technology*, 22(2):33-39.
- Petts, G.E., **R. Sparks** and I. Campbell. 2000. River restoration in developed economies. Pages 494-508 in P.J. Boon, B.R. Davies, G.E. Petts eds. *Global Perspectives on River Conservation: Science, Policy and Practice*. John Wiley & Sons Ltd. Chichester, England.
- Sparks, R.E.** 1995. Value and need for ecological management of large river-floodplain ecosystems. *BioScience* 45(3):168-182.
- Church, M., J. Gardiner, K. Lubinski, R. Meade, G. Petts, **R.E. Sparks**, J. Ward, and R.L. Welcomme. 1995. Sustaining the ecological integrity of large floodplain rivers: Application of ecological knowledge to river management. Conference and Workshop

Summary. National Biological Service, Environmental Management Technical Center, Onalaska, WI. 21 p.

Sparks, R.E. 1993. Making predictions that change the future: forecasts and alternative visions for the Illinois River. Keynote Speech at the Third Biennial Governor's Conference on the Management of the Illinois River System. Illinois Natural History Survey, Center for Aquatic Ecology Technical Report 93/18. 23 p.

National Research Council 1992. Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. National Research Council, Commission on Geosciences, Environment and Resources. National Academy Press. Washington, D.C. As chairman of the Subcommittee on Rivers and Streams, **R.E. Sparks** prepared most of Chapter 5, Rivers and Streams, (Pages 149-242), as well as the following case studies: The Upper Mississippi River (Pages 377-381); The Illinois River-Floodplain Ecosystem (Pages 382-399); and The Atchafalaya Basin (Pages 370-376).

Swanson, F.J., and **R.E. Sparks**. 1990. Long-term ecological research and the invisible place. The local to global spatial scales of the Long-Term Ecological Research (LTER) Program. *BioScience* 40(7):502-508.

Webster, J., E. Blood, K. Cummings, M. Gurtz, and **R.E. Sparks**. 1985. Long-term research in stream ecology. *Bulletin of the Ecological Society of America* 66(3):346-353.

Invasive species

Sparks, Richard E., Tracy L. Barkley, Sara M. Creque, John M. Dettmers, and Karen M. Stainbrook. 2011. Evaluation of an electric fish dispersal barrier in the Chicago Sanitary and Ship Canal. Pages 139-161 in Duane C. Chapman and Michael H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society Symposium 74.

Schneider, D.W., J.A. Stoeckel, C.R. Rehmann, K. D. Blodgett, **R. E. Sparks**, D. K. Padilla. 2003. A developmental bottleneck in dispersing larvae: implications for spatial population dynamics. *Ecology Letters* 6:352-360.

Schneider, D.W., S.P. Madon, J.A. Stoeckel, and **R.E. Sparks**. 1998. Seston quality controls zebra mussel (*Dreissena polymorpha*) energetics in turbid rivers. *Oecologia* 117:331-341

Madon, S.P., D.W. Schneider, J.A. Stoeckel, and **R.E. Sparks**. 1998. Effects of inorganic sediment and food concentrations on energetic processes of the zebra mussel, *Dreissena polymorpha*: Implications for growth in turbid rivers. *Canadian Journal of Fisheries and Aquatic Sciences* 55:401-413.

Madon, S.P., D.W. Schneider, J.A. Stoeckel, and **R.E. Sparks**. 1998. *In situ* determination of zebra mussel metabolic rates using the electron transport system (ETS) enzyme assay: field applications. *Journal of Shellfish Research* 17:195-203.

Stoeckel, J.A., D.W. Schneider, L.A. Soeken, K.D. Blodgett and **R.E. Sparks**. 1997. Propagule dynamics of a riverine metapopulation: Implications for zebra mussel recruitment, dispersal and control in a large-river system. *Journal of the North American Benthological Society* 16(3):586-601.

Stoeckel, J.A., L. Camlin, K.D. Blodgett, and **R.E. Sparks**. 1996. Establishment of *Daphnia lumholtzi* (an exotic zooplankter) in the Illinois River. *Journal of Freshwater Ecology* 11(3):377-379.

Raibley, P.T., K.D. Blodgett, and **R.E. Sparks**. 1995. Grass carp (*Ctenopharyngodon idella*) in the Upper Mississippi River. *Journal of Freshwater Ecology* 10(1):65-74.

- Thompson, C.M. and **R.E. Sparks**. 1978. Comparative nutritional value of a native fingernail clam and the introduced Asiatic clam. *Journal of Wildlife Management* 42:391-396.
- Thompson, C.M. and **R.E. Sparks**. 1977. Improbability of dispersal of adult Asiatic clams, *Corbicula manilensis*, via the intestinal tract of migratory waterfowl. *American Midland Naturalist* 98(1):219-223.
- Thompson, C.M. and **R.E. Sparks**. 1977. The Asiatic clam, *Corbicula manilensis*, in the Illinois River. *The Nautilus* 91(1):34-36.
- Anderson, K.B., C.M. Thompson, **R.E. Sparks**, and A.A. Paparo. 1976. See full citation under Aquatic toxicology, water quality.

Aquatic toxicology, water quality

- Sparks, R.E.**, P.E. Ross, and F.S. Dillon. 1993. Identification of toxic substances in the upper Illinois River. Final Report. Illinois Department of Energy and Natural Resources, Springfield, IL. ILENR/RE-WR-92/07. 59 p.
- Sparks, R.E.** 1984. The role of contaminants in the decline of the Illinois River: implications for the Upper Mississippi. Pages 25-65 in J.G. Wiener, R.V. Anderson, and D.R. McConville, eds. *Contaminants in the Upper Mississippi River*. Butterworth Publishers, Stoneham, MA. 384 p.
- Butts, T.A., R.L. Evans, and **R.E. Sparks**. 1982. Sediment oxygen demand--fingernail clam relationships in the Mississippi River Keokuk Pool. *Transactions of the Illinois State Academy of Science* 75(1-2):29-39.
- Lubinski, K.S., and **R.E. Sparks**. 1981. Use of bluegill toxicity indexes in Illinois. Pages 324-337 in D.R. Branson and K.L. Dickson, eds. *Aquatic toxicology and hazard assessment: fourth conference*. ASTM STP 737. American Society for Testing and Materials. Philadelphia, PA.
- Paparo, A.A., and **R.E. Sparks**. 1980. Ionophore-mediated calcium control of ciliary arrest in the fingernail clam, *Musculium transversum*. *Comparative Biochemistry and Physiology* 66:355-357.
- Sallee, R.D., R.E. Sparks, C.M. Thompson, and D.A. White. 1977. Zinc toxicity to the bluegill (*Lepomis macrochirus*). *Transactions of the Illinois State Academy of Science* 70(2):213.
- Anderson, K.B., C.M. Thompson, **R.E. Sparks**, and A.A. Paparo. 1976. Effects of potassium on adult Asiatic clams, *Corbicula manilensis*. Illinois Natural History Survey Biological Notes No. 98. 7 pages.
- Cairns, J., Jr., and **R.E. Sparks**. 1971. Special application and procedures for bioassay. Pages B3-1 to B3-10 in *Bioassay in pollution analysis and control*. Training manual, Office of Water Programs, Environmental Protection Agency, Cincinnati, OH.
- Waller, W.T., M.L. Dahlberg, **R.E. Sparks**, and J. Cairns, Jr. 1971. A computer simulation of the effects of superimposed mortality due to pollutants on populations of fathead minnows (*Pimephales promelas*). *Journal Fisheries Research Board of Canada* 28(8):1107-1112.

Ecological theory

- Sparks, R.E.**, and A.J. Spink. 1998. Disturbance, succession and ecosystem processes in rivers and estuaries: effects of extreme hydrologic events. *Regulated Rivers* 14(2):155-177.
- W.H. Romme, E.H. Everham, L.E. Frelich, M. Moritz, and **R. E. Sparks**. 1998. Are large, infrequent disturbances qualitatively different from small, frequent disturbances? *Ecosystems* 1(6): 524-534.
- Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegard, B.D. Richter, **R.E. Sparks**, and J.C. Stromberg. 1997. The natural flow regime. *Bioscience* 47(11):769-784. (Note: authors listed alphabetically after lead author, Poff.)
- Sparks, R.E.**, P.B. Bayley, S.L. Kohler, and L.L. Osborne. 1990. Disturbance and recovery of large floodplain rivers. *Environmental Management* 14(5):699-709.
- Junk, W., P.B. Bayley, and **R.E. Sparks**. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127 in D.P. Dodge, ed. Proceedings of the International Large River Symposium (LARS). *Canadian Special Publication of Fisheries and Aquatic Sciences* 106.

Fisheries, fish ecology, fish population monitoring, impact assessment

- Raibley, P.T., K.S. Irons, T.M. O'Hara, K.D. Blodgett, and **R.E. Sparks**. 1997. Winter habitats used by largemouth bass in the Illinois River, a large river-floodplain ecosystem. *North American Journal of Fisheries Management* 17:401-412
- Raibley, P.T., T.M. O'Hara, K.S. Irons, K.D. Blodgett, and **R.E. Sparks**. 1997. Largemouth bass size distributions under varying annual hydrological regimes in the Illinois River. *Transactions of the American Fisheries Society* 126:850-856.
- Lerczak, T.V., and **R.E. Sparks**. 1995. Fish populations in the Illinois River. Pages 239-241 in National Biological Service National Status and Trends Report. U.S. Government Printing Office, Washington, D.C. 530 p.
- Fremling, C.R., J.L. Rasmussen, **R.E. Sparks**, S.P. Cobb, C.F. Bryan, and T.O. Claflin. 1989. Mississippi River fisheries: a case history. Pages 309-351 in D.P. Dodge, ed. Proceedings of the International Large River Symposium (LARS). *Canadian Special Publication of Fisheries and Aquatic Sciences* 106.
- Sparks, R.E.**, F.C. Bellrose, F.L. Pavaglio, Jr., M.J. Sandusky, D.W. Steffeck, and C.M. Thompson. 1979. Fish and wildlife habitat changes resulting from construction of a nine-foot navigation channel on pools 24, 25, and 26 of the Mississippi River and the lower Illinois River. Report prepared for the U.S. Army Corps of Engineers, St. Louis District. 217 pages.
- F.C. Bellrose, **R.E. Sparks**, F.L. Pavaglio, Jr., D.W. Steffeck, R.C. Thomas, R.A. Weaver, and D. Moll. 1977. Fish and wildlife habitat changes resulting from construction of a nine-foot navigation channel in the Illinois Waterway from LaGrange Lock & Dam upstream to Lockport Lock & Dam. Contract Report DACW 23-76-C-0066 prepared for the U.S. Army Corps of Engineers, Chicago District. 176 pages.
- Sparks, R.E.** and W.C. Starrett. 1975. An electrofishing survey of the Illinois River, 1959-1974. *Illinois Natural History Survey Bulletin* 31(Article 8):317-380.

Sparks, R.E. 1975. Environmental inventory and assessment of navigation pools 24, 25, and 26, Upper Mississippi River and lower Illinois rivers: An electrofishing survey of the Illinois River. Contract No. DACW39-74-M-3084. Report to the Environmental Effects Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 122 pages.

Floods and flooding

Atterberry, R., K. Brown, M. Demissie, G.J.D. Hewings, W.C. Kling, E.E. Knowles, J.P. Marxman, S.A. McConkey, C. McKillip, R.B. Olshansky, A. Russell, **R.E. Sparks**, R.E. Warner, and A. Zwilling. 2010. Aftermath of the floods of June 2008 and recommendations for long-term economic recovery. Final report of the Illinois Long Term Recovery Council to Governor Pat Quinn & the people of Illinois. Prepared by the Office of Sustainability, Office of the Vice Chancellor for Public Engagement, University of Illinois at Urbana-Champaign. Contracted by the Illinois Department of Commerce & Economic Opportunity. Funded by the U.S. Department of Commerce, Economic Development Administration.

Sparks, R.E., J. Nelson, Y. Yin. 1998. Naturalization of the flood regime in regulated rivers: the case of the upper Mississippi River. *BioScience* 48(9):706-720.

Theiling, C.H., R.J. Maher, and **R.E. Sparks**. 1996. Effects of variable annual hydrology on a river regulated for navigation. *Journal of Freshwater Ecology* 11(1):101-114.

Sparks, R.E. 1996. Ecosystem effects: positive and negative outcomes. Pages 132-162 in S.A. Changnon, ed. *The Great Flood of 1993. Causes, Impacts, and Responses*. Westview Press, Boulder, CO.

Bhowmik, N.G., A.G. Buck, S.A. Changnon, R.H. Dalton, A. Durgunoglu, M. Demissie, A.R. Juhl, H.V. Kunkel, S.A. McConkey, R.W. Scott, K.P. Singh, T.-W. Soong, **R.E. Sparks**, A.P. Visocky, D.R. Vonnahme, and W.M. Wendland. 1994. The 1993 flood of the Mississippi River in Illinois. Illinois State Water Survey, Champaign, IL. Miscellaneous Publication 151. 149 p.

Sparks, R.E. 1993. Fisheries and the flood of '93. *Fisheries* 18(12):18-19.

Sparks, R.E. 1992. Risks of altering the hydrologic regime of large rivers. Pages 119-152 in J. Cairns, Jr., B.R. Niederlehner, and D.R. Orvos, eds. *Predicting Ecosystem Risk*. Advances in Modern Environmental Toxicology. Volume XX. Princeton Scientific Publishing Company, Incorporated, Princeton, N.J. 347p.

Hydrology

Lian, Y.Q., J-Y You, **R. E. Sparks**, and M. Demissie. 2012. Impact of human activities to hydrologic alterations on the Illinois River. American Society of Civil Engineers, *Journal of Hydrologic Engineering* 17(4):537-546.

Macroinvertebrates, including freshwater mussels and clams

- Corti, D., S.L. Kohler, and **R.E. Sparks**. 1997. Effects of hydroperiod and predation on a Mississippi River floodplain invertebrate community. *Oecologia* 109:154-165.
- Wilson, D.M., T.J. Naimo, J.G. Wiener, R.V. Anderson, M.B. Sandheinrich, and **R.E. Sparks**. 1995. Declining populations of the fingernail clam *Musculium transversum* in the Upper Mississippi River. *Hydrobiologia* 304:209-220.

Monitoring, conventional

- Sparks, R.E.**, and K.D. Blodgett. 1992. The relationship between long-term monitoring and short-term problem assessment techniques in management of large river-floodplain ecosystems. *In*: Technical Information Workshop Notebook: Biological Assessment in Large Rivers. North American Benthological Society. Annual Meeting. 26-29 May. Louisville, KY.
- Sparks, R.E.** 1987. Improving methods of data analysis and interpretation for environmental management programs. Pages 37-48 *in* S. Draggan, J.J. Cohrssen, and R.E. Morrison, eds. Environmental monitoring, assessment, and management: the agenda for long-term research and development. National Science Foundation and the President's Council on Environmental Quality. Praeger Publishers, New York, NY. 128 p.
- Cairns, J., Jr., **R.E. Sparks**, and W.T. Waller. 1973. The relationship between continuous biological monitoring and water quality standards for chronic exposure. Pages 383-402 *in* G.E. Glass, ed. Bioassay techniques and environmental chemistry. Ann Arbor Science Publishers, Incorporated, Ann Arbor, MI.

Monitoring, using aquatic organisms as sensors in real time monitoring systems

- Paparo, A.A., and **R.E. Sparks**. 1977. Rapid assessment of water quality using the fingernail clam, *Musculium transversum*. Pages 96-109 *in* J. Cairns, Jr., K.L. Dickson, and G.F. Westlake, eds. Biological monitoring of water and effluent quality. American Society for Testing and Materials, ASTM STP 607, Philadelphia, PA.
- Cairns, J., Jr., G.R. Lanza, **R.E. Sparks**, and W.T. Waller. 1973. Developing biological information systems for water quality management. *Water Resources Bulletin* 9(1):81-99.
- Cairns, J., Jr., **R.E. Sparks**, and W.T. Waller. 1973. The design of a continuous flow biological early warning system for industrial use. Pages 242-255 in 27th Annual Purdue Industrial Waste Conference, 2-4 May 1972. Purdue University Engineering Bulletin.
- Cairns, J., Jr., **R.E. Sparks**, and W.T. Waller. 1973. The use of fish as sensors in industrial waste lines to prevent fish kills. *Hydrobiologia* 41(2):151-167.
- Sparks, R.E.** and J. Cairns, Jr. 1972. The response of bluegill sunfish (*Lepomis macrochirus* Rafinesque) to seismic shock. *Hydrobiologia* 39(2):273-276.
- Cairns, J., Jr., K.L. Dickson, **R.E. Sparks**, and W.T. Waller. 1970. A preliminary report on rapid biological information systems for water pollution control. *Journal Water Pollution Control Federation* 42(5)Part 1:685-703.

Nutrients

Spink, A., **R.E. Sparks**, M. van Oorschot, and J.A. Verhoeven. 1998. Nutrient dynamics of large river floodplains. *Regulated Rivers* 14(2): 203-216.

Predictive impact models and decision support for naturalization/restoration of rivers

- Sparks, R. E.** & J.B. Braden. 2007. Naturalization of developed floodplains: an integrated analysis. *Journal of Contemporary Water Research and Education*, **136**:7-16.
- Ahn, C., K.F. Moser, **R.E. Sparks** & D.C. White. 2007. Developing a dynamic model to predict the recruitment and early survival of black willow (*Salix nigra*) in response to different hydrologic conditions. *Ecological Modelling*, 204(3-4):315-325.
- Nedovic-Budic, Z., R.G. Kan, D.M. Johnston, **R.E. Sparks** & D.C. White. 2006. Community Viz™-based model for assessing development impacts in a naturalized floodplain – Emiquon Viz. *Journal of Urban Planning and Development* 132(4):201-210.
- Ahn, C., D.M. Johnston, **R.E. Sparks** & D.C. White. 2006. Analysis of naturalization alternatives for the recovery of moist-soil plants in the floodplain of the Illinois River. *Hydrobiologia* 565:217-228. Also printed as a book chapter, pages 217-228 in R.S.E.W. Leuven, A.M.J. Ragas, A.J.M. Smits, and G. van der Velde (eds.) *Living Rivers: Trends and Challenges in Science and Management*. Springer, Dordrecht, The Netherlands.
- Sparks, R.**, C. Ahn, M. Demissie, A. Isserman, D. Johnston, Y. Lian, Z. Nedovic-Budic, & D. White. 2005. Linking hydrodynamics, conservation biology, and economics in choosing naturalization alternatives for the Illinois River, USA. *Archiv für Hydrobiologie Supplement* 155/1-4:521-538.
- Ahn, C., **R.E. Sparks** and D.C. White. 2004. A dynamic model to predict responses of millets (*Echinochloa sp.*) to different hydrologic conditions for the Illinois floodplain-river. *River Research and Applications* **20**(5): 485-498.
- Ahn, C., D. C. White & **R. E. Sparks**. 2004. Moist-soil plants as ecohydrologic indicators for recovering the flood pulse in the Illinois River. *Restoration Ecology* 12(2):207-213.
- Koel, T.M. and **R.E. Sparks**. 2002. Historical patterns of river stage and fish communities as criteria for operations of dams on the Illinois River. *River Research and Applications* 18(1):3-19.
- Sparks, R.**, J. Braden, M. Demissie, P. Mitra, D. Schneider, D. White, R. Xia. 2000. Technical support of public decisions to restore floodplain ecosystems: a status report on the Illinois River project, USA. Pages 225-247 in A.J.M Smits, P.H. Nienhuis, R.S.E.W. Leuven eds. *New Approaches to River Management*. Backhuys Publishers, Leiden, Netherlands.

Rivers and streams, general

Kohler, S.L., M.F. Kubacki, **R.E. Sparks**, T.V. Lerczak, D. Soluk, P.B. Bayley, K.S. Cummings, M.A. Harris, L.M. Page, S.G. Gough, and C.H. Theiling. 1994. Flowing waters. Pages

171-224 in *The Changing Illinois Environment: Critical Trends. Volume 3. Ecological Resources*. Illinois Department of Energy and Natural Resources, Springfield. ILENR/RE-EA-94/05. 242 p.

Sparks, R.E., and R.M. Sparks. 1992. The Mississippi River. *Restoration and Management Notes* 10(1):39-44.

Sediment

Bhowmik, N.G., J.R. Adams, and **R.E. Sparks**. 1986. Fate of a navigation pool on the Mississippi River. *Journal of Hydraulic Engineering* 112(10):967-970.

Steffeck, D.W., F.L. Paveglio, Jr., F.C. Bellrose, and **R.E. Sparks**. 1980. Effects of decreasing water depths on the sedimentation rate of Illinois River bottomland lakes. *Water Resources Bulletin* 16(3):553-555.

Sparks, R.E., R.C. Thomas, and D.J. Schaeffer. 1980. The effects of barge traffic on suspended sediment and turbidity in the Illinois River. Report prepared for the U.S. Fish and Wildlife Service, Rock Island Field Office, Ecological Services. 68 pages. See also Robert C. Thomas' M.S. thesis, 1981, Western Illinois University, Macomb, IL.

Vegetation, primary production

See the three papers on plants in the **Predictive Impacts** category above: Ahn C., **R.E. Sparks** and D.C. White (2004); Ahn, C., D.C. White & **R.E. Sparks** (2004); Ahn, C., K.F. Moser, **R.E. Sparks** & D.C. White (2007). Also, see

Nelson, J.C., **R.E. Sparks**, L. DeHaan, and L. Robinson. 1998. Presettlement and contemporary vegetation pattern along two navigation reaches of the Upper Mississippi River. Pages 51-60 in T.D. Sisk (ed.) *Perspective on the land-use history of North America: A context for understanding our changing environment*. U.S. Geological Survey, Biological Resources Division. Biological Science Report USGS/BRD/BSR-1998-0003. 104 pages.

Nelson, J.C., and **R.E. Sparks**. 1998. Forest compositional change at the confluence of the Illinois and Mississippi rivers. *Transactions of the Illinois Academy of Science* 91(1/2):33-46.

Nelson, J.C., A. Redmond, and **R.E. Sparks**. 1994. Impacts of settlement on floodplain vegetation at the confluence of the Illinois and Mississippi rivers. *Transactions of the Illinois Academy of Science* 87(3/4):117-133.

Grubaugh, J.W., R.V. Anderson, D.M. Day, K.S. Lubinski, and **R.E. Sparks**. 1986. Production and fate of organic material from *Sagittaria latifolia* and *Nelumbo lutea* on Pool 19, Mississippi River. *Journal of Freshwater Ecology* 3(4):477-484.

Attachment E
Comments of the Conservation Organizations

On the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)



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25 November 2013

SUBJECT: Comments on the July 2013 Draft Environmental Impact Statement for the St. Johns Bayou and New Madrid Floodway Project

Dear Colonel Anderson,

I have previously provided comments and testimony regarding the St. Johns Bayou/New Madrid Floodway project and its impacts on waterfowl and shorebirds. I provided comments on earlier versions of the environmental impact statement, including the Revised Supplemental EIS2 (December 2005).

I am Associate Professor in the Department of Fisheries and Wildlife at Oregon State University and have been conducting research on the ecology, conservation, and management of waterfowl since 1987, including work in the Mississippi Alluvial Valley in Arkansas and Missouri. I have 22 peer reviewed publications since 2000 dealing with aspects of waterfowl and wetland ecology, many of which directly relate to issues germane to the proposed project. In my position as a university professor I teach or have taught courses in wetland ecology and management, waterfowl ecology, avian ecology, and ornithology.

In this letter I provide comments on the new waterfowl and shorebird analyses of project impacts and mitigation. I appreciate that the US Army Corps of Engineers (hereafter referred to as the Corp) developed a more specific process for calculating DUDs and included an external scientific review of the biological models used to estimate impacts and that the Corp's new WAM analysis is based on a more rigorous effort to characterize the foraging value of various habitat types in their calculations of DUDs. However, this improvement does not overcome all of my concerns and leads me to conclude that the proposed mitigation will not replace all the lost functions and values provided by the current system.

I. Waterfowl

General description of site as being important to waterfowl

The New Madrid Floodway/St. Johns Bayou area lies at the northern end of the Mississippi Alluvial Valley (MAV), one the most significant areas for migrating and wintering waterfowl in

North America (Bellrose 1980). More than 80% of the historic wetlands in the Lower MAV have been lost, which makes the remaining wetlands exceedingly valuable (Fredrickson 1978). Common waterfowl using the area during the non-breeding season include Mallard (*Anas platyrhynchos*), Wood Duck (*Aix sponsa*), Northern Pintail (*Anas acuta*), Green-winged Teal (*A. crecca*), Northern Shoveler (*A. clypeata*), Gadwall (*A. strepera*), American Wigeon (*A. americana*), Blue-winged Teal (*A. discors*), Lesser Scaup (*Aythya affinis*), Ring-necked duck (*A. collaris*) and Hooded Merganser (*Lophodytes cucullatus*). Wood Ducks are common breeders and Hooded Mergansers are locally common breeders. Mallard and Blue-winged Teal also nest in the area in small numbers. These species rely on a diversity of wetland habitats including flooded forest, scrub-shrub, moist soil (seasonal herbaceous), flooded agricultural fields and open water during different times of the evaluation period (November 1 to March 31) to meet their nutritional and behavioral needs (Reinecke et al. 1989).

Waterfowl Assessment Model (WAM)

The current WAM that calculates Duck Use Days (DUD) and uses DUDs as the metric for comparing current project impacts to future scenarios is a significant improvement over the model contained in the previous DEIS. The WAM is a tool for calculating available food supplies for certain ducks likely to be provided by various habitats. The model relies on more recent data related to food production and a more recent understanding of the relationship between body size and Resting Metabolic Rate (Miller and Eadie 2006) than the previous DEIS. Having acknowledged that, there are several significant problems that are not addressed.

1. The mitigation emphasizes reforestation and the food supply for ducks that use forested habitats, the most common and abundant of which are mallards and wood ducks. That means the mitigation plan ignores ducks that do not commonly use forested wetlands, which are the substantial majority of duck species, and includes diving ducks as well as dabbling ducks that use more open habitats. Although mallards and wood ducks represent the majority of ducks using the project area, all duck species using the system need to be accounted for by the mitigation. While forested wetlands dominated the project area prior to human modifications, the large areas of open habitats created by conversion to agriculture has attracted and now support a more diverse group of species that need to be expressly considered in mitigation. There is nothing in the model to expressly recognize this dichotomy. Further, many of the DUD days post project are attributable to acorns and Mallards and Wood Ducks are the only waterfowl species that commonly consume acorns. Thus, food available to those species that do not eat acorns will further decline with mitigation. Moreover, the mitigation plan ignores the fact that reforestation represents a further reduction in usable acres to species like pintail that prefer more open habitats like seasonal herbaceous wetlands.

2. Food is not the only factor that is important for valuing habitat. Relying solely on DUDs to assess project impacts assumes food is the only critical resource that should be considered when mitigating project impacts for waterfowl, which is not true. For example, February and March are critical to spring migrating waterfowl that are molting and acquiring energy reserves that will be used in migration and on the breeding grounds to form eggs. Behavioral patterns during this period indicate that compared to winter, birds in late winter and spring seek spatial isolation (Heitmeyer 1985), thus it takes more acres to support the same number of birds. Isolation can partially be achieved using vegetation, but not entirely. Similarly, survival is influenced by multiple factors that include disease, and disease transmission increases with bird density. Calculations of mitigation acres needed should include some consideration for the need for spatial isolation during the Feb-Mar period. Therefore, calculating mitigation acreage based solely on bird energy needs under represents what is actually needed to replace lost functions in the system.
3. Mitigation lands should be identified and acquired before project construction begins. The Corp has purchased one, 1,000 acre track (Bogle Woods); however, because acquisition is constrained by the need to buy from “willing sellers”, there is no assurance the remaining lands will be acquired close to existing wetland areas for restoration, particularly lands already cleared for agriculture. Landowners provided with increased protection from flooding as a result of the proposed project may be unwilling to sell. Landowners may also be more reluctant to sell given recent increases in commodity prices driven in part by federal ethanol fuel standards. If these factors result in mitigation lands being distributed among small isolated tracts, the benefits to waterfowl and other wetland wildlife will be greatly reduced.
4. These problems are substantial. They mean that even if the mitigation plan adequately replaces food supplies for ducks that use forested wetlands, the mitigation does not address other duck needs or the needs of many duck species. As my testimony in a water quality certification hearing in Missouri goes into, the project area provides valuable habitat for these other species and the large reductions in flooding will greatly reduce that habitat. That testimony, which I understand is still a part of the record, remains valid. That means by definition that the mitigation does not offset the project impacts.

Mitigation plan

Table 16 of the Mitigation Technical Document (Appendix R) finds that the project and planned mitigation will result in an increase in 2.3 million DUDs in the New Madrid Basin during February and March. However, that conclusion relies in part on crediting duck habitat that already exists, and on some estimates of food values that I find questionable.

- a. 1.4 million of those DUDs are attributed to habitat at 10 Mile Pond, an area that already exists. Preservation or inclusion of existing lands as a mitigation strategy is, from a biological perspective, inappropriate as it does not replace lost wetland values for waterfowl.
- b. The mitigation plan double counts seasonal herbaceous wetlands as providing value for both shorebirds and waterfowl. It is true that seasonal herbaceous wetlands provide habitat for waterfowl and shorebirds, but in practice managing such habitats to maximize their value for one taxa precludes maximizing their value for the other taxa (see explanation in shorebirds below). There is no consideration for such conflicts in the mitigation plan.
- c. It is not clear how the value of batture lands was arrived at for mitigation because the documentation does not indicate how food values were arrived for such lands (Table 16, Appendix R). The Corp stipulates that batture areas will largely reforest to cottonwood and willow. Such species produce little food for waterfowl, which implies that these areas should produce few DUDs, yet, almost 1.8 million DUDs are attributed to this habitat type. Without additional justification for the value of batture areas, this habitat should not be counted. Moreover, deep flooding in batture area habitats may render what little food is produced unavailable to waterfowl.
- d. Estimates of the project's impact on wetland losses assume ground water hydrology will not be significantly altered. However, it has been shown elsewhere that the channel modifications proposed in the project can lower ground water levels (Maki et al. 1980, Luckey 1985). If true, then wetland losses may be greater than predicted, which could significantly increase the project impacts on waterfowl. Although the Corps believes subsurface hydrology will not be significantly altered, the DEIS does not provide adequate documentation to verify their claim.

Even if additional information clarifies any or all of the issues raised above, given the foraging value of forested habitats is greatly dependent upon acorn production, project construction should not occur until mitigation lands have been planted long enough for trees to start producing acorns, which is not currently part of the mitigation plan.

Together, the issues raised above indicate the proposed mitigation will not fully compensate for lost habitat value from project construction.

II. Shorebirds

The connectivity between the river and floodplain in the New Madrid Floodway creates a unique wetland complex for migrating shorebirds along the Mississippi River Drainage. Although data about shorebird use of the project site are lacking, the large area of diverse floodplain wetlands scattered across the New Madrid Floodway/St. Johns Bayou area provides habitat for a wide

range of shorebird species. Species commonly using floodplain wetlands in the project area include Pectoral Sandpiper (*Calidris melanotos*), Semipalmated Sandpiper (*Calidris pusilla*), Least Sandpiper (*Calidris minutilla*), Lesser Yellowlegs (*Tringa flavipes*), Greater Yellowlegs (*Tringa melanoleuca*), and Common Snipe (*Gallinago gallinago*). Shorebirds require habitats that are shallow and sparsely vegetated, thus flooded agriculture wetlands and seasonal herbaceous (moist soil) wetlands are the most important resource to shorebirds in the project area. Although farmed wetlands have limited value for some species of wildlife, they offer valuable shorebird habitat because disking and plowing set back vegetation succession keeping these wetlands available for shorebirds (Helmers 1992).

The Corp has expressed the view that, because shorebirds did not historically occur in the project area, they are not obligated to mitigate for this group of species. They also state that failure to mitigate for shorebirds is not a problem because they "...would likely relocate to other agricultural fields, sand bars, and marshlands in the Mississippi River Valley and elsewhere." (DEIS Appendix R, pp 23-24). The statement begs the question "to which habitat are they referring?" The project area is the only reach along the lower Mississippi River where overbank flooding creates shorebird habitat in the floodplain; that fact provides evidence that this area is critically important for shorebirds and needs to be protected. I concur that forested wetlands should be emphasized in mitigation, but that does not justify ignoring impacts on shorebirds and waterfowl that will not use flooded forests.

As with the WAM model, the approach to assessing impacts to shorebirds has improved since the previous assessment conducted and expressed last in 2005 and 2006; however, the results from this analysis have been misapplied when generating the mitigation plan for shorebirds with the result being that the mitigation plan does not fully compensate for project related losses to shorebirds.

The shorebird assessment in the DEIS (Appendix H, part 1) estimates that under current conditions there is an average of 946 ha of suitable foraging habitat available **per day** during spring migration for shorebirds, with approximately 489 ha of that being rated as "optimal". The proposed project will reduce that value by around 30% in the St. John Basin and greater than 98% in the New Madrid Basin. The Corps claims that it could mitigate for these impacts through the almost permanent flooding for the 93 day shorebird season of a 1,286 acre parcel. The Corps then proposes to achieve this mitigation primarily by claiming credit for seasonal herbaceous wetlands already present at 10 Mile Pond plus several hundred acres of managed seasonally flooded agricultural habitats. There are several major problems with this plan:

- a. As noted above for waterfowl, counting previously established habitat as mitigation does not replace lost wetland values. 10 Mile Pond already exists, so simply counting it towards mitigation does not mitigate anything.

- b. The Corp assumes that flooding roughly 1,000 acres for 93 consecutive days is equivalent to flooding a much larger area whose location moves in response to variable flooding and that on average provides 1,000 acres of shallow flooded habitat useable by shorebirds over those 93 days. That would only be true if the food supply were equivalent. Stagnant flooding on one site for 93 consecutive days increases the likelihood of food depletion, which lowers the value of that habitat patch over time. The shorebird model as constructed cannot be applied to such fundamentally different circumstances. It is possible that the depletion effects could be somewhat offset if the biomass of invertebrates would be initially higher in the managed area or invertebrate production in the managed area were high, but there are no data presented that justify either assumption and neither is likely to allow such a small area to match the food value of the much larger, naturally flooded project site.
- c. Although the project claims shorebird value for 10 Mile Pond, it will not be possible to maximize the value of seasonal herbaceous wetlands concomitantly for waterfowl and shorebirds. At a minimum, the value of seasonal herbaceous habitats at 10 Mile Pond attributed to both shorebirds and waterfowl would need to be adjusted down. For example, traditional management of seasonal herbaceous wetlands (aka moist soil habitats) for waterfowl during fall migration and winter in the project area includes a spring drawdown the preceding season, which exposes soil and provides conditions for robust growth of herbaceous plants that provide foods like seeds and tubers. The vegetation is flooded during fall or early winter to make foods available to migrating waterfowl (Fredrickson and Taylor 1982, Fredrickson and Reid 1986). Robust emergent vegetation is not used by shorebirds, which feed on benthic invertebrates and require sparsely vegetated, very shallowly flooded habitats (Helmert 1992, Twedt et al. 1998).

Thus, managing for fall migrating ducks lowers the value of seasonal herbaceous wetlands for shorebirds during the same period. By spring, much vegetation will have senesced creating suitable conditions for shorebirds, but some amount of vegetation will remain that continues to preclude use by shorebirds. Managing for maximum shorebird use of the same wetland would include a late summer mowing or disking of the plants that might interfere with plant seed or tuber production (i.e., waterfowl food) but would create large openings in wetland and turn under organic matter that would help support the growth of benthic invertebrate populations (Fredrickson and Reid 1986).
- d. Areas planned for reforestation will further reduce the acres of habitat suitable for shorebirds. Few shorebirds use forested wetlands; thus, plans to replant or naturally recruit thousands of acres of flooded cropland will actually further reduce shorebird habitat. This fact was ignored in the DEIS.
- e. Concentrating shorebirds onto just a few properties likely will generate more attention by predators, which will decrease the time available for foraging and shrink the functional size



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of mitigation habitats. Finally, increasing shorebird density will increase risk of disease transmission.

These problems with the shorebird mitigation are significant. Overall, they imply that mitigation for shorebird impacts would be modest at best. They individually and collectively preclude me from concluding that impacts on shorebirds are fully impacted, and their use of the project area is ecologically important.

The views expressed are to true and correct to the best of my knowledge, information, and belief. I make them subject to penalties for unsworn falsifications to authorities.

Regards,

A handwritten signature in black ink, appearing to read "Bruce Dugger".

Bruce Dugger, PhD
Associate Professor

Literature Cited

- Bellrose, F. C. 1980. Ducks, geese & swans of North America. Stackpole Books, Harrisburg.
- Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. *Journal of Wildlife Management*. 50:392-397.
- Drobney, R. D. and L. H. Fredrickson. 1979. Food selection by wood ducks in relations to breeding status. *Journal of Wildlife Management*. 43:109-120.
- Dugger, B. D., Dugger, K. M., and Fredrickson, L. H. 1994. Hooded merganser. *in* Birds of North America, No. 98 (A. Poole and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, D. C.: The American Ornithologist Union.
- Fredrickson, L. H. 1978. Lowland hardwood wetlands: current status and habitat values for wildlife. Pgs. 296-306 *in* Wetlands functions and Values: the State of our Understanding. American Water Resources Association.
- Fredrickson, L. H. and Reid, F. A. 1986. Wetland and riparian habitats: a nongame management overview. Pgs. 60-95 *in* Management of Nongame Wildlife in the Midwest: a Developing Art [J. B. Hale, L. B. Best, and R. L. Clawson, Eds.]. Proceedings of a symposium held at the 47th Midwest Fish and Wildlife Conference.

- Fredrickson, L. H. and Taylor, T. S. 1982. Management of Seasonally Flooded Impoundments for Wildlife. 148: 1-29.
- Heitmeyer, M. E. 1985. Wintering strategies of female mallards related to dynamics of lowland hardwood wetlands in the upper Mississippi delta. Ph.D. dissertation, University of Missouri, Columbia, 360 pp.
- Heitmeyer, M. E., Fredrickson, L. H., and Krause, G. F. 1989. Water and habitat dynamics of the Mingo Swamp in southeastern Missouri. U. S. Fish and Wildlife Service, Fish and Wildlife Research Report 6. 26 pp.
- Helmers, D. L. 1992. Shorebird Management Manual. Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts.
- Klimas, C. V. 1989. Limitations on ecosystem function in the forested corridor along the lower Mississippi River. Proceedings of the International Symposium on Wetlands and River Corridor Management. Assoc. State Wetland Managers Inc., Berne, NY
- Luckey, R. R. 1985. Water resources of the southeast lowlands, Missouri. Water Investigations Report 84-4277. U.S. Geological Survey, Rolla, Missouri. 78 pp.
- Maki, T. E., A. J. Weber, D. W. Harzel, S. C. Hunter, B. T. Hyberg, D. M. Flinchum, J. P. Lollis, J. B. Rognstad and J. D. Gregory. 1980. Effects of stream channelization on bottomland and swamp forest ecosystems. Water Resources Research Institute, University of North Carolina, Raleigh, North Carolina. 135 pp.
- Miller, M.R. and J.M. Eadie. 2006. The allometric relationship between resting metabolic rate and body mass in wild waterfowl (Anatidae) and an application to estimation of winter habitat requirements. Condor 108:166-177
- Reinecke, K. J., R. M. Kaminski, D. J. Moorhead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pgs 203-247 in Habitat management for migrating and wintering waterfowl in North America [L. M. Smith, R. L. Pederson, and R. M. Kaminski eds.]. Texas Tech Univ. Press, Lubbock.
- Twedt, D. J., C. O. Nelms, V. E. Rettig, and S. R. Aycock. 1998. Shorebird use of managed wetlands in the Mississippi Alluvial Valley. American Midland Naturalist 140:140-152.
- U.S. Fish and Wildlife Service, Office of Migratory Bird Management. 2013. Waterfowl Population Status, 2013.

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EDUCATION

1996. **Ph.D., Wildlife Ecology, University of Missouri, Columbia, MO.** Dissertation title: Impact of conspecific brood parasitism on host fitness in two species of diving ducks. Dissertation supervisor: Dr. Leigh H. Fredrickson.
1990. **M.S., Wildlife Ecology, University of Missouri, Columbia, MO.** Thesis title: Late winter ecology of female mallards in the Mississippi Alluvial Valley. Thesis supervisor: Dr. Leigh H. Fredrickson.
1986. **B.S., Fisheries and Wildlife, University of California, Davis, CA.**

MAJOR INTERESTS

Behavioral ecology of waterbirds; conservation planning; ecology, management and conservation of waterbirds and their wetland habitats; science planning and policy; species habitat relationships; watchable wildlife; wetland ecology, management and restoration.

EMPLOYMENT HISTORY

- 2008-present. **Associate Professor**, Dept. of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331
- 2005-2008. **Mace Assistant Professor of Watchable Wildlife**, OSU.
- 2002-2004. **Assistant Professor**, Dept. of Fisheries and Wildlife, Oregon State Univ.
- 1998-2001. **Assistant Professor**, Cooperative Wildlife Research Lab and Department of Zoology, Southern Illinois University, Carbondale.
- 1996-1998. **Post-doctoral ornithologist**, MacArthur Agro-Ecology Research Center, Archbold Biological Station, Lake Placid, FL.
- 1995-1996. **Lecturer**, Biology Department, University of Missouri Columbia, MO.
1995. **Research Associate**, Department of Fisheries and Wildlife, University of Missouri Columbia, MO.
- 1987-1994. **Graduate Research or Teaching Assistant**, Department of Fisheries and Wildlife, University of Missouri Columbia, MO
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TEACHING EXPERIENCE

I have taught multiple courses at the graduate and undergraduate level both on campus and via distance education. Course sizes have ranged from 6 – 180 students and format has ranged from graduate level reading and discussion courses to large, lower division lecture courses.

Courses Taught (grad courses underlined)

Mizzou - Ornithology, Ecology

SIU - Waterfowl ecology & Management (Zoo436), Wetland Ecology, Avian Ecology

OSU - Principles of Fish and Wildlife Conservation (FW251), Ornithology (FW311) – both on campus and distance education, Systematics of Birds (FW312), Group Problem Solving (FW441-443), Avian Conservation and Management (FW451/551), Wetland and Riparian Ecology (FW479/579) – both on campus and online, Problem Solving in Fish and Wildlife (FW488).

Graduate Education: Provided mentorship to 14 masters students, 3 doctoral students and 1 post doctoral researcher.

PUBLICATIONS

Refereed

- . Ivey, G. L., **B. D. Dugger**, C. P. Herziger, M. L. Casazza, J. P. Fleskes. Distribution, abundance, and timing of arrival and departure of Greater and Lesser Sandhill Cranes wintering in the Sacramento and San Joaquin River Delta region of California. *in press*. Proceedings of the North American Crane Workshop 12: xxx-xxx.
- . Ivey, G. L., **B. D. Dugger**, C. P. Herziger, M. L. Casazza, J. P. Fleskes. Characteristics of sandhill crane roosts in the Sacramento-San Joaquin Delta of California. *in press*. Proceedings of the North American Crane Workshop 12: xxx-xxx.
- . Barbaree, B., K. Nelson, **B. D. Dugger**, et al. Nesting Ecology of Marbled Murrelets breeding in an isolated sound in SE Alaska. *Condor in press*.
- 2013. Wyss, L. A., **B. D. Dugger**, A. T. Herlihy, W. J. Gerth, and J. L. Li. Effects of grass seed agriculture on aquatic invertebrate communities inhabiting seasonal wetlands on the southern Willamette Valley, Oregon. *Wetlands in press*
- 2012. Evans-Peters, G. R., **B. D. Dugger**, and M. J. Petrie. Plant community composition and waterfowl food production on Wetland Reserve Program easements in western Oregon and Washington. *Wetlands* 32:391-399.
- 2011. Maggiulli, N. M., and **B. D. Dugger**. Factors Associated with Dusky Canada Goose (*Branta canadensis occidentalis*) Nesting and Nest Success on Artificial Nest Islands of the Western Copper River Delta. *Waterbirds* 34:269-279.
- 2011. Mueller-Warrant, G., Mueller-Warrant, G.W., G.W. Whittaker, S.M. Griffith, G.M. Banowetz, **B.D. Dugger**, T.S. Garcia, G., Giannico, K. L. Boyer, and B.C. McComb. Remote sensing classification of grass seed cropping practices in western Oregon. *International Journal of Remote Sensing* 32:2451-2480..
- 2010. **Dugger, B. D.**, J. Finger, and S. Melvin. Nesting Ecology of Mottled Ducks in Florida. *Wildfowl* 60:95-105.
- 2010. Strycker, N. K., J. V. Boydston, J. D. Graves, L. L. Bristow, and **B. D. Dugger**. Use of Himalayan Blackberry Patches by Wintering Birds in Western Oregon. *Oregon Birds* 35:57-62.
- 2009. **Dugger, B. D.** and J. Feddersen. Managing river flows to improve habitat quality for waterfowl on a large, regulated River. *Wildfowl* 59:62-74.
- 2009. Greer, D. M., **B. D. Dugger**, K. J. Reinecke, and M. J. Petrie. Depletion of rice as food of waterfowl wintering in the Mississippi Alluvial Valley. *Journal of Wildlife Management* 75:1125-1133.

2008. Wongsriphuek, C, B. D. Dugger, and AM Bartuszevige. 2008. Dispersal of Wetland Plant Seeds by Mallards; the Influence of gut passage on recovery, retention, and germination. *Wetlands* 28:290-299.
2008. Ivey, GL, and **BD Dugger**. Factors influencing Greater Sandhill Crane nest success at Malheur National Wildlife Refuge, Oregon. *Waterbirds* 31:52-61.
2008. Uyehara, KJ, A. Engilis, and **BD Dugger**. Wetland features that influence occupancy by endangered Hawaiian Duck. *Wilson Journal of Ornithology* 120:311-319.
2007. Rashford, BS, **BD Dugger**, and RM Adams. Application of a bioeconomic optimization model to improve waterfowl management. *Journal of Wildlife Management* 72:510-517.
2007. **Dugger BD**, ML Cline, RS Finger, and MJ Petrie. True metabolizable energy of four common moist-soil seed species in the western U.S. *Journal of Wildlife Management* 71:1964-1967.
2007. Greer, A., **BD Dugger**, D Graber, and MJ Petrie. Influence of spring flooding on food availability to spring migrating waterfowl. *Journal of Wildlife Management* 71:1561-1566.
2006. Haig SM, E Beever, SM Chambers, HM Draheim, **BD Dugger**, S Dunham, E Elliott-Smith, J Fontaine, DC Kesler, BJ Knaus, IF Lopes, P Loschl, TD Mullins, and LM Sheffield. Taxonomic Considerations in Listing Subspecies Under the U.S. Endangered Species Act. *Conservation Biology* 20:1584-1594.
2005. **Dugger, B. D.**, S. L. Melvin, R. S. Finger. Abundance and community composition of waterfowl and wading birds using the channelized Kissimmee River Floodplain, Florida. *Southeastern Naturalist* 4:435-446.
2004. Babineau, F. B., **B. D. Dugger**, D. Holm, and A. Woolf. Winter distribution and habitat use of Trumpeter swans in Illinois. *North American Swans* 32:166-174.
2001. **Dugger, B. D.** and P. Blums. Impact of conspecific brood parasitism on host fitness for Tufted Duck and Common Pochard. *Auk*: 118:717-726.
2000. **Dugger, B. D.** and M. J. Petrie. Geographic variation in foraging patterns of pre-incubating female Mallards. *Canadian Journal of Zoology* 78:2240-2243.
1999. **Dugger, B. D.**, P. Blums, and L. H. Fredrickson. Response of female Common Pochards and Tufted Ducks to brood parasitism. *Wildfowl* 50:71-78.
1999. Dugger, K. M., **B. D. Dugger**, and L. H. Fredrickson. Annual survival of female Hooded Mergansers and Wood Ducks in southeast Missouri. *Wilson Bulletin* 111:1-6.
1999. **Dugger, B. D.**, and L. H. Fredrickson. Response of female Hooded Mergansers to the eggs of an interspecific parasite. *Auk* 116: 269-274.
1998. Anderson, D. H. and **B. D. Dugger**. A conceptual basis for evaluating restoration success. *Trans. North Am. Wildlife and Nat. Res. Conference* 63:1-7.
1998. Ryan, M. R. and **B. D. Dugger**. Audio tapes vs. computer software for studying bird songs: the value of active learning. *Nat. Resour. and Environ. Issues*. 7:183-185.
1997. **Dugger, B. D.** Factors influencing the onset of spring migration in Mallards. *J. of Field Ornithology* 68:331-337.
1994. **Dugger, B. D.**, K. J. Reinecke, and L. H. Fredrickson. Late winter survival of female mallards in Arkansas. *Journal of Wildlife Management* 58:94-99.

Book Chapters/Symposia Proceedings

2014. Williams, C., **B.D. Dugger**, Ryan A. Boyer, Michael G. Brasher, Paul M. Castelli, Dane M. Cramer, John M. Coluccy, John M. Eadie, Joseph P. Fleskes, Matthew J. Gray, Heath M. Hagy, Jeremiah R. Heise, Orrin E. Jones, David Jones-Farrand, Richard M. Kaminski, Richard A. McKinney, Matt L. Miller, Luke Naylor, Aaron T. Pearse, Mark J. Petrie,

- Samantha Richman, Kevin M. Ringelman, Jeffrey C. Schank, Michael L. Schummer, Gregory J. Soulliere, Joshua D. Stafford, John M. Tirpak, Josh Vest, Elisabeth B. Webb. Estimating habitat carrying capacity for waterfowl: considerations, pitfalls, and improvements.
2013. Mini, A.E., E. Harrington, E. Rucker, **B.D. Dugger**, and T. Mowbray. American Wigeon (*Anas americana*). The Birds of North America On-line (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, New York.
2009. Dugger, B. D., K. M. Dugger and L. H. Fredrickson. Hooded Merganser (*Lophodytes cucullatus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/098doi:10.2173/bna.98>
2004. **Dugger, B. D.** Ecology and management of Canada Geese in North America. Proceedings International Symposium on Migratory Birds 1:1-10. Gunsan, Korea.
2003. **Dugger, B. D.**, and K. M. Dugger. Long-billed Curlew. Pp. 224-226 in Birds of Oregon: A general reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis, OR.
2002. **Dugger, B. D.** and K. M. Dugger. The long-billed curlew (*Numenius americanus*). In The Birds of North America, No. 628 (A. Poole, P. Stettenheim, and F. Gill, eds.). Philadelphia: The Academy of Natural Sciences; Washington, DC; The American Ornithologists' Union.
1994. **Dugger, B. D.** and K. M. Dugger, L. H. Fredrickson. The Hooded Merganser (*Lophodytes cucullatus*). In Birds of North America, No. 98 (A. Poole and F. Gill Eds.). Philadelphia: The Academy of Natural Sciences; Washington D. C.: The American Ornithologists' Union.

Technical/Extension Publications

2011. Wyss, L. A., A. T. Herlihy, **B. D. Dugger**, J. L. Li, W. J. Gerth, and G. R. Giannico. Grass Seed Agriculture and Invertebrate Communities of Seasonal Wetlands in the Southern Willamette Valley. 2010 Seed Production Research at Oregon State University. Ext/CrS 130:45-48.
2009. Livia V. Lins, R. D. Andrade; A. L. Neto; R. D. Hearn, B. Hughes, **B. D. Dugger**, L. M. Scoss, F. Ribeiro, I. R. Lamas, and S. E. Rigueira. Capture and Marking of the Brazilian Merganser in Serra Da Canastra Region of Minas Gerais, Brazil. Threatened Waterfowl Specialist Group Bulletin.
2006. B. Hughes, **B. D. Dugger**, H. J. Cunha, I. Lamas, J. Goerck, L. Lins, L. F. Silveira, R. Andrade, S. F. Bruno, S. Rigueira. Y. de Melo Barros. Action Plan the Brazilian Merganser (*Mergus octosetaceus*). IBAMA Threatened Species Series – n° 3
2005. G. E. Williams, **B. D. Dugger**, and S. L. Melvin. Winter Abundance of Waterfowl on the Floodplain. in Anderson, D. H., S. G. Bousquin, G. E. Williams, and D. J. Colangelo, editors. 2005. Defining success: expectations for restoration of the Kissimmee River. South Florida Water Management. District, West Palm Beach, Florida, USA. Technical Publication ERA #433.
1999. **Dugger, B. D.** and S. L. Melvin. Using ducks to evaluate the success of river floodplain restoration. Duck Specialist Group Bulletin 2:15-18.
1993. Fredrickson, L. H., and **B. D. Dugger**. Management of wetlands at high altitudes in the southwest. U.S. Forest Serv., Southwest Region 71 pp.

Select Reports

2012. Edge, W. D.; Dugger, B.; Giannico, G.; Gregory, S. V.; Heppell, Selina.; Robinson, W. D.; Rossignol, P. A.; DeBano, S.; Wooster, D.; Garcia, T. S.; Noakes, D. L.; add Sidlauskas.

- Conservation and Restoration of Aquatic, Marine and Terrestrial Ecosystems. Final Federal Agricultural Experiment Station Report, CSREES, Washington D.C. 35pp.
2010. Fox, T., B. D. Dugger, and K. M. Dugger. Survey Protocol for Monitoring the Relative Abundance of Sooty Grouse (*Dendragapus fuliginosus fuliginosus*) Populations in Western Oregon. Report to Oregon Department of Fish and Wildlife. 110pp.
2009. Tirpak, J. M., M. G. Brasher, **B. D. Dugger**, J. M. Eadie, R. S. Holbrook, K. J. Reinecke, R. R. Reker, G. J. Soulliere, W. B. Uihlein, and B. C. Wilson. Linking Winter Waterfowl Habitat to Survival: Challenges and Opportunities in Measuring Conservation Effects. North American Waterfowl Management Plan Steering Committee. 33pp.
2009. Fox, T., B. D. Dugger, and K. M. Dugger. Survey of Sooty Grouse (*Dendragapus fuliginosus fuliginosus*) Abundance in Western Oregon: a pilot study of encounter rates and detection distances. Report to Oregon Department of Fish and Wildlife. 21pp.
2007. **Dugger, B. D.**, M. J. Petrie, and D. Mauser. A Bioenergetic Approach to Conservation Planning for Waterfowl at Lower Klamath and Tule Lake National Wildlife Refuge. Technical Report submitted to USFWS. 110pp.
2003. **Dugger, B. D.**, and A. K. Greer. Influence of fall vs. spring flooding on the availability of seed resources to spring migrating waterfowl. Final Report submitted to Missouri Department of Conservation.
2003. **Dugger, B. D.**, and F. B. Babineau. Wintering ecology of wintering Trumpeter Swans wintering in southern Illinois. Final report submitted to Illinois Dept. of Natural Resources. Fed Aid
2003. **Dugger, B. D.**, and M. L. Cline. Nest success of Giant Canada Geese in northeast Illinois. Final report submitted to MaxMcGraw Wildlife Foundation.
2003. Garvey, J. E, **B. D. Dugger**, M. R. Whiles, S. R. Adams, M. B. Flinn, B. M. Burr, R. J. Sheehan, and K. M. Dugger. Responses of Fishes, Waterbirds, Invertebrates, Vegetation, and Water Quality to Environmental Pool Management: Mississippi River Pool 25. Final report submitted to U.S. Army Corps of Engineers, St. Louis District.
2002. **Dugger B. D.**, and J. Nawrot. Habitat preferences of migratory shorebirds and waterfowl on the east shoreline of Rend Lake Refuge. Final Report for Federal Aid Project W-142-R-01 submitted to Illinois Dept. of Natural Resources.
2000. **Dugger, B. D.** and J. C. Feddersen. Evaluation of Environmental Pool Management as a tool for producing waterbird habitat on the Upper Mississippi River. Final Report, U. S. Army Corps. of Engineers. 76pp.

GRANTS AND CONTRACTS

- 2013-2017. **Dugger, B. D.**, C. M. Malachowski, and K. Uyehara. Removal of Invasive Mallards and hybrids from Hanalei National Wildlife Refuge. USFWS Invasive Species Program. \$38,229.
- 2012-2013. Malachowski, C. M. and **B. D. Dugger**. Population Dynamics, movement patterns, and habitat use of endangered Koloa maoli on Kaua'i. Kilauea Point Natural History Association. \$10,000.
- 2012-2015. **Dugger, B. D.** The impact of fencing taro loi on the abundance and behavior of endangered waterbirds in Hawaii. USFWS. \$106,000
- 2012-2013. **Dugger, B. D.**, D. Heard, and K. Uyehara. Health Assessment of Hawaiian Duck

- at Hanalei National Wildlife Refuge. USFWS. \$34,428
- 2012-2013. A. E. Mini, and **Dugger, B. D.** and. Cackling Goose Agricultural Depredation in Willamette Valley and Lower Columbia River: Quantifying Carrying Capacity, Habitat Use, and Movements to Define Management Options. \$23,700
- 2011-2012. **Dugger, B. D.** Synthesis manuscripts. \$35,000
- 2011-2012. **Dugger, B. D.** Klamath Monograph. Ducks Unlimited. \$22,000
- 2011-2013. **Dugger, B. D.** and C. P. Malachowski. Demographic Factors Limiting Recovery of Endangered Hawaiian Duck. Pacific Coast Joint Venture. \$50,000.
- 2011-2014. M. Reynolds, **B. D. Dugger**, K. Uyehara, and C. P. Malachowski. Demographic Factors Limiting Recovery of Endangered Hawaiian Duck. USGS/USFWS Science Support Program. \$74,983.
- 2010-2012. **Dugger, B. D.**, and C. P. Malachowski. Monitoring population size of endangered Hawaiian duck and removal of Hawaiian Duck-mallard hybrids from Hanalei NWR. \$79,518.
- 2009-2012. **Dugger, B. D.** Role of introduced wild Turkeys in Pacific Northwest ecosystems. Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, U. S. Forest Service. \$166,000.
- 2009-2011. **Dugger, B. D.** Factors limiting recovery of the Hawaiian Duck. U.S. Fish and Wildlife Service. \$44,642.
- 2009-2010. **Dugger, B. D.** and K. M. Dugger. Designing a survey of Sooty Grouse in western Oregon. Oregon Department of Fish and Wildlife, \$32,000.
- 2008-2010. K. Nelson and **B. D. Dugger**. Alaska Department of Fish and Game. Habitat use and movements of Marbled Murrelets. \$262,477.
- 2007-2011. **Dugger, B. D.** Wetland management on ODFW Wildlife Management Areas. Oregon Department of Fish and Wildlife. \$52,000.
- 2007-2010. **Dugger, B. D.** A biological assessment of WRP wetlands for wintering waterbirds. Ducks Unlimited, Pacific Coast Joint Venture, Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. \$120,000.
- 2007-2010. M Casazza, **Dugger, BD**, G Ivey, J Fleskes, and R Anthony. Sandhill Crane use of Agricultural Lands in the Sacramento-San Joaquin Delta Region. CALFED. \$493,000.
- 2006-2007. Giannico, G, S Grosskopf, TS Garcia, B McComb, R Confessor, **BD Dugger**, J Li, A Herlihy, and R Fare. Assessing Trade-offs Between Crop Production and Ecological Services: The Calapooia Basin. USDA - CSREES, \$659,571
- 2006-2008. Ivey, G, and **BD Dugger**. Comparative winter ecology of Greater and Lesser Sandhill Cranes wintering the San Joaquin Delta region of California. Felburn Foundation. \$50,000.
- 2006-2007. **Dugger, BD**, and A Mini. Comparative foraging ecology of Dusky Canada and Cackling geese wintering in the Willamette Valley, OR. \$20,000.
2006. **Dugger, BD**, and A Mini. Nutritional quality of grass crops used by wintering Canada Geese in the Willamette Valley, OR. Oregon Department of Fish and Wildlife. \$10,000.
- 2006-2007. **Dugger, BD**. Nest success of Dusky Canada Geese nesting on man-made islands in the Copper River Delta. USDA Forest Service. \$42,500.
- 2005-2009. **Dugger, BD**. Oregon Department of Fish and Wildlife. Evaluation of wetland management practices on ODFW management areas. \$51,000.
- 2005-2007. **Dugger, BD**. Carrying capacity of Great Salt Lake wetlands for migratory waterbirds. Ducks Unlimited. \$100,000.
- 2005-2007. **Dugger, BD** and MJ Petrie. Factors limiting recruitment of mallards in eastern

- Washington. Washington Department of Fish and Game. \$180,000.
- 2005-2006. Petrie, M. J. and **BD Dugger**. Conservation planning for migratory waterfowl in Puget Sound. \$39,000. Pacific Coast Joint Venture, Washington Department of Fish and Wildlife.
- 2005-2006. C. Wongsripheuk, **BD Dugger** and P. Kennedy. The role of birds as dispersers of wetland plant seeds. Thailand Government. \$17,680
- 2003-2004. G. Ivey and **BD Dugger**. Nesting ecology of Greater Sandhill Cranes in eastern Oregon. Western Crane Working Group. \$18,000.
- 2002-2004. **Dugger, BD** Carrying capacity of seasonal wetlands for migratory waterbirds at Lower Klamath and Tule Lake NWR. USFWS. \$149,000.
- 2002-2004. **Dugger, BD** Factors influencing home range size of breeding Mallards in the Great Lakes region. Ducks Unlimited. \$35,000.
- 2001-03. **Dugger, BD** Winter Ecology of Trumpeter Swans in southern Illinois. Illinois Dept. of Natural Resources. \$104,428.
- 2001-02. **Dugger, BD** and J. Nawrot. Habitat use by migratory shorebirds and Canada Geese at Rend Lake Wildlife Refuge. Illinois Dept. of Natural Resources. \$99,176.
- 2000-2002. Sheehan R. J., **B. D. Dugger**, S. R. Adams, M. R. Whiles, and B. M. Burr. Response of Fish, Invertebrates, Vegetation, Waterbirds, and Water Quality to Environmental Pool Management: Mississippi River Pool 25. U. S. Army Corp of Engineers. \$64,023.
- 2000-02. **Dugger, B. D.**, M. J. Petrie, D. Graber. Consequences of managing wetlands for fall flooding on the availability of food for ducks during spring migration. Ducks Unlimited-Institute for Wetland and Waterfowl Research; U.S. Fish and Wildlife Service, Region 3 Migratory Birds; Missouri Dept. of Conservation, \$65,000.
- 2000-02. Reinecke, K. J., M. J. Petrie, **B. D. Dugger**, R. Kaminski. Over winter seed depletion by waterfowl wintering in the Lower Mississippi Alluvial Valley. North American Wetland Conservation Act Evaluation Program. \$100,000.
2000. **Dugger, B. D.** Conservation workshop for the Brazilian Merganser, September 2000, Belo Horizonte, Brazil. U.S. Fish and Wildlife Service, Office of International Affairs. \$5,400.
- 2000-02. **Dugger, B. D.** Reproductive Ecology of Giant Canada Geese. MaxMcGraw Wildlife Foundation. \$40,000.
1999. Woolf, A. and **B. D. Dugger**. Mississippi Flyway Parts Collection Survey. U.S. Fish and Wildlife Service, Office Migratory Bird Management. \$11,500.
- 1998-00. **Dugger, B. D.** and B. Sheehan. Evaluating the efficacy of moist-soil management techniques on regulated, large river systems. U. S. Army Corp of Engineers. \$76,000.
- 1998-99. **Dugger, B. D.** Reproductive Ecology of Mottled Ducks. South Florida Water Management District. \$75,000.
- 1996-98. Bancroft, T. and **B. D. Dugger**. Using waterfowl to evaluate restoration of the Kissimmee River. South Florida Water Management District. \$176,000.
1995. **Dugger, B. D.** and M. J. Petrie. Macro habitat comparisons of Mallard time-activity budgets: a test of the Food Limitation Hypothesis. Delta Waterfowl Research Station. \$2,000.
- 1992-93. **Dugger, B. D.** Estimating the cost of conspecific brood parasitism to host female Tufted ducks and Common Pochards. Delta Waterfowl Research Station. .

PRESENTATIONS

2013. Malachowski, C. M., C. P. Wells, **B. D. Dugger** (presenter), and A. Engilis. Ecology and Conservation of an Island Endemic Bird: the Hawaiian Duck on Kauai. Avian Ecology Study Group (AVES), Oregon State University. (invited talk)
2013. **Dugger, B. D.**, M. Brasher, J. Mc. Eadie, M. J. Petrie, J. Tirpak, G. Soulliere, J. Vest, L. Naylor, D. T. Jones-Farrand. The Science Behind Conservation Planning for Migratory Waterfowl in North America: Considerations for Moving Forward Under the Assumption of Winter Food Limitation During the Non-breeding Season. Presentation at the Ecology and Conservation of North American Waterfowl Conference. Memphis, TN. (invited talk)
2013. McWilliams, S. R., S. Richman, R. A. McKinney, C. K. Williams, and **B. D. Dugger**. Estimating daily energy expenditure of waterfowl: allometric models should work but may not. Presentation Ecology and Conservation of North American Waterfowl Conference. Memphis, TN (invited talk).
2013. Eadie, J. Mc., K. M. Ringelman, M. L. Miller, J. C. Schank **B. D. Dugger**, and M. J. Petrie. Using agent-based models to inform habitat planning for wintering waterfowl. Presentation at the Ecology and Conservation of North American Waterfowl Conference. Memphis, TN (invited talk).
2013. **Dugger, B. D.**, T. T. Fox, J. M. Coluccy, K. M. Dugger, M. J. Petrie, and D. Kraege. Breeding Ecology of Mallards in Eastern Washington. Poster at at Ecology and Conservation of North American Waterfowl Conference. Memphis, TN.
2013. Malachowski, C. M., and **B. D. Dugger**. Hawaiian Duck behavior and response to wetland management at Hanalei National Wildlife Refuge. Poster at at Ecology and Conservation of North American Waterfowl Conference. Memphis, TN.
2013. Malachowski, C. M., C. J. Billat, K. J. Uyehara, and **B. D. Dugger**. Reducing Hybridization Threats to Endangered Hawaiian Duck in Core Habitats in Hawai'i. Poster at at Ecology and Conservation of North American Waterfowl Conference. Memphis, TN.
2013. Mini, A. E., and **B. D. Dugger**. Carrying Capacity of Publicly Owned Lands for Canada and Cackling Geese Wintering in Western Oregon. Poster at at Ecology and Conservation of North American Waterfowl Conference. Memphis, TN.
2013. Evans-Peters, G. R., **B. D. Dugger**, and M.J. Petrie. Value of Wetlands Created via the Wetlands Reserve Program as Waterfowl Foraging Habitat. Presented at Pacific Flyway Science Symposium, Otter Crest, OR.
2013. Evans-Peters, G. R., **B. D. Dugger**, and M.J. Petrie. Food Availability: Distribution of Wetland Plant Seeds in Seasonal Wetlands. Poster at Ecology and Conservation of North American Waterfowl Conference. Memphis, TN.
2013. Evans-Peters, S. T., and **B. D. Dugger**. 2013. Foraging Ecology and Seed Dispersal Potential of Wild Turkeys in Oregon and Washington. Presented at The National Wild Turkey Annual National Convention, Nashville, TN.
2012. Malachowski, C. P., and **B. D. Dugger**. 2012. Hawaiian Duck (*Anas wyvilliana*) behavior and response to wetland habitat management at Hanalei National Wildlife Refuge, Kaua'i. *Poster presentation*, The Wildlife Society 19t Annual Conference, Portland, OR.
2012. Mini, A. E., and **B. D. Dugger**. Winter Conservation Planning for Cackling Geese. Presentation to Pacific Flyway Study Committee, Cackling Canada Goose Subcommittee, Spokane, Washington (invited talk).
2012. Barbaree, B. A., S. K. Nelson, **B. D. Dugger**, S. H. Newman, Nesting Ecology of Marbled Murrelets in Port Snettisham, Southeast Alaska. Poster presented at the North American

- Ornithological Conference, Vancouver, B.C. August 2012.
2012. **Dugger, B. D.**, M. Brasher, J. Mc. Eadie, M. J. Petrie, J. Tirpak, G. Soulliere, J. Vest, L. Naylor, D. T. Jones-Farrand. The Science Behind Conservation Planning for Migratory Waterfowl in North America: Evidence for Food Limitation During the Non-breeding Season. Presentation the International Wildlife Management Congress, Durban, South Africa. July 2012.
2012. Paroulek, S. T., and **B. D. Dugger**. Diet and Seed Dispersal Capabilities of Wild Turkeys in the Pacific Northwest. Presented at The Wildlife Society Annual Oregon Chapter Meeting, Lincoln City, OR.
2012. **Dugger, B. D.**, C. M. Malachowski, and K. J. Uyehara. Detection of mallard-Hawaiian Duck hybrids at Hanalei National Wildlife Refuge. Talk to Hawaii Chapter of the Pacific Coast Joint Venture, Lihue, HI June 2012. (**invited talk**)
2012. **Dugger, B. D.** Research on Hawaiian Ducks: current activities and a vision for future research. Talk to Ecological Services and Refuges Office of USFWS. Honolulu, HI. June 2012. (**invited talk**)
2012. Ivey, G. L., and **B. D. Dugger**. Movements and home ranges of greater and lesser sandhill cranes in the Sacramento-San Joaquin Delta of California. Presented at The Wildlife Society Annual Oregon Chapter Meeting, Lincoln City, OR.
2012. Evans-Peters, G.R., **B.D. Dugger**, and M.J. Petrie. Plant Community Composition and Waterfowl Food Production on Wetland Preserve Program Easements Compared to Those on Managed Public Lands in Western Oregon and Washington. Presented at Oregon chapter of The Wildlife Society's annual conference, Lincoln City, OR.
2011. Malachowski, C. P., and **B. D. Dugger**. 2011. Over view of Koloa maoli Research conducted at Hanalei NWR, HI. Seminar, Department of Wildlife, Fish, & Conservation Biology, University of California, Davis, CA. (**invited talk**)
2011. Herlihy, A. T., L. A. Wyss, W. J. Gerth, **B. D. Dugger**, G. W. Whittaker, and G. R. Giannico. 2011. The effects of conservation practices on biota in southern Willamette Valley intermittent streams and wetlands. Presented at the annual meeting of the Northwest Biological Assessment Workgroup, Stevenson, WA.
2011. **Dugger, B. D. Invited plenary**. Conservation planning for Hawaiian waterbirds: linking habitat objectives to population size. Hawaiian Waterbirds Conference, Honolulu, HI.
2011. Malachowski, C. P. and **Dugger, B. D.** Daily and Seasonal Movements by Endangered Koloa maoli on Kaua'i. Hawaiian Waterbirds Conference, Honolulu, HI.
2011. Billat, C. J., K. J. Uyehara, C. P. Malachowski, **B. D. Dugger**, M. E. Dalton, and C. C. Smith. Reducing Hybridization Threats to Endangered Koloa Maoli in Core Habitats at Hanalei and Hulē'ia National Wildlife Refuges. *Poster presentation*, Hawaiian Waterbirds Conference, Honolulu, HI.
2011. A. E. Mini, and **B. D. Dugger**. Foraging Along a Body Size Gradient: A Comparison of Cackling and Canada Geese Wintering in Western Oregon. Presentation at the 12th North American Arctic Goose Symposium, Portland Oregon, Jan. 2011.
2011. A. E. Mini, and **B. D. Dugger**. An Allometric Analysis of Body Size and Gut Morphology in Canada and Cackling Geese. Poster at the 12th North American Arctic Goose Symposium, Portland Oregon, Jan. 2011.
2011. Wyss, L. A., **B. D. Dugger**, and A. T. Herlihy. Aquatic Invertebrate communities among three seasonal wetland land-use habitats in the southern Willamette Valley, Oregon. Presentation at Oregon Chapter of The Wildlife Society, Bend Oregon, Feb. 2011.
2011. Ivey, G. L., **B. D. Dugger**, M. L. Casazza, J. P. Fleskes, and Caroline P. Herziger. Use of

- the Sacramento-San Joaquin Delta Region of California by wintering Greater and Lesser Sandhill Cranes. Presentation at Waterbirds Society Meeting, Kearney Nebraska, March 2011.
2011. Ivey, G. L., **B. D. Dugger**, M. L. Casazza, J. P. Fleskes, and Caroline P. Herziger. Movements and home range size of Greater and Lesser Sandhill Cranes wintering in Central California. Presentation at Waterbirds Society Meeting, Kearney Nebraska, March 2011.
2011. Paroulek, S. T., and **B. D. Dugger**. Wild Turkey Biology and Foraging Ecology in the Pacific Northwest. Presented at Oregon Hunter Association Youth Hunt Day, The Dalles, OR.
2010. B. D. Dugger, **W. D. Edge**, S. S. Heppell, and S. A. Heppell. Designing a capstone course in Fisheries and Wildlife: a case history from Oregon State University. The Wildlife Society, Ogden, Utah, October (**invited talk**).
2010. Ivey, G. L., **B. D. Dugger**, J. P. Fleskes, and C. P. Herziger. Migration timing, abundance and distribution of sandhill cranes in the Sacramento-San Joaquin Delta. Bay-Delta Science Conference, Sacramento, CA, September.
2010. **B. D. Dugger**. Embarrassment of Riches: conservation and management of Canada geese in the Willamette Valley, Oregon. Fisheries and Wildlife Departmental Seminar, Corvallis, OR.
2010. Ivey, G. L., **B. D. Dugger**, and C. P. Herziger. Migration route and winter range of lesser sandhill cranes breeding near Homer, Alaska. Oregon Chapter The Wildlife Society. February.
2010. B. A. Barbaree, S. K. Nelson, **B. D. Dugger**, S. H. Newman. Breeding Ecology of Marbled Murrelets in Port Snettisham, Southeast Alaska. First World Seabird Conference, Vancouver, B.C.
2010. Herlihy, A. G. W. Whittaker, G. W. Mueller-Warrant, S. M. Griffith, J. Li, G. Giannico, K. Boyer, T. S. Garcia, B. McComb, **B. D. Dugger**, S. Grosskopf. Assessing Trade-offs Between Crop Production and Ecological Services in the Willamette Valley, Oregon - the Calapooia CEAP Study. Managing Agricultural Landscapes II Workshop. Denver, CO.
2010. Paroulek, S. T., and **B. D. Dugger**. Wild Turkey Foraging Ecology in the Pacific Northwest Project Progress. Presented at Oregon Hunters Association Banquet, Bend, OR.
2010. Paroulek, S. T., and **B. D. Dugger**. 2010. Wild Turkey Foraging Ecology in the Pacific Northwest Project Progress. Presented at Washington Department of Fish and Wildlife Annual Wildlife Program Meeting, Olympia WA.
2009. Paroulek, S. T., and **B. D. Dugger**. 2009. Wild Turkey Foraging Ecology in the Pacific Northwest Project Progress. Presented at National Wild Turkey Federation Annual Meeting, Salem, OR.
2009. G. L. Ivey, Casazza, M. L., **Dugger, B. D.**, Fleskes, J. D., and Herziger, C. P. Comparison of greater and lesser sandhill crane winter movements in California. Annual meeting, The Wildlife Society, Monterrey, CA.
2009. **B. D. Dugger**, M. J. Petrie, and D. Mauser. Using Bioenergetic Models for Conservation Planning in the Klamath Basin, California. North American Duck Symposium, Toronto, ON.
2009. John M. Tirpak, M. G. Brasher, **B. D. Dugger**, J. M. Eadie, R. S. Holbrook, K. J. Reinecke, R. R. Reker, G. J. Soulliere, W. B. Uihlein, and B. C. Wilson. Linking Winter Waterfowl Habitat to Survival: Challenges and Opportunities in Measuring Conservation Effect. North American Duck Symposium, Toronto, ON.
2009. **Dugger, B. D.** and N. Maggilli. 2009. Factors influencing use of nest islands by Dusky

- Canada Geese breeding on the Copper River Delta, AK. OTWS meeting, Glen Eden Beach, OR.
2009. G. R. Evans-Peters and **B. D. Dugger**. Assessment of Waterfowl Food Resources in WRP and Public Land in Western Oregon and Southwest Washington. Poster. North American Duck Symposium, Toronto, ON.
2009. A. E. Mini, **B. D. Dugger**, and M. J. Petrie. Nutritional Analysis of Grass Habitats for Grazing Waterfowl Wintering in the Willamette Valley, Oregon. Poster. North American Duck Symposium, Toronto, ON.
2008. **Dugger, B. D.**, W. D. Edge, J. Li. Incorporating Outcome Assessment into an Undergraduate Fisheries and Wildlife Curriculum. University Education Natural Resource Conference, Corvallis, Oregon.
2008. Mini, A. E., and **B. D. Dugger**. Comparative Foraging Ecology of Two Sympatric Herbivores, Dusky Canada Goose and Cackling Goose, in the Willamette Valley, Oregon. American Ornithologist Union, Portland Oregon.
2007. Petrie, M, **BD Dugger**, R Finger, J. Fleskes, R. Holbrook, D. Kraege, D Mauser, M Moore, R Shaffer, and C. Smith. Establishing Habitat Objectives for Wintering and Migrating Waterfowl in the Pacific Flyway: A Progress Report. Oral presentation. Pacific Flyway Science Symposium, Newport, OR, March.
2007. Ivey, GL, and **BD Dugger**. Factors influencing Greater Sandhill Crane nest success at Malheur National Wildlife Refuge, Oregon. Oral presentation. Pacific Flyway Science Symposium, Newport, OR, March.
2007. **Dugger BD**, C Wongsriphuek, and AM Bartuszevige. Endozoochorous dispersal of wetland plant seeds by mallards. Oral Presentation. Oregon/Washington Joint TWS meeting. Pendleton, OR, April.
2007. Wongsriphuek, C, **BD Dugger**, and AM Bartuszevige. Mallards as seed dispersers: gut retention time, seed retrieval and germination of different wetland plant species. Oral Presentation. 2nd International Field Ecology Symposium, Bang Khun Tien, Bangkok, Thailand.
2007. Uyehara, K. J., Engilis, A., Jr., Reynolds, M., Marshall, A. P., and **BD Dugger**. Conservation of Hawaiian Duck: Research and Management Needs. Poster. Hawaii Conservation Conference, Honolulu, HI, July 25-27, 2007.
2006. **Dugger, BD**, J. McA Eadie, and MJ Petrie. Conservation planning for wintering waterfowl: an assessment of status and needs. *Invited Plenary Presentation*. 4th North American Duck Symposium, Bismarck ND.
2006. Rashford, BS, and **BD Dugger**. Of ducks and dollars: improving the cost-effectiveness of waterfowl management in the Prairie Pothole region. Verbal Presentation. 4th North American Duck Symposium, Bismarck ND.
2006. Uyehara, K. J., Engilis, A., Jr., Michelle Reynolds, AP Marshall, and **BD Dugger**. Conservation of Hawaiian Duck: research and management needs. Poster presentation, 4th North American Duck Symposium, Bismarck ND.
2006. Johnson A, BD Dugger, and MJ Petrie. Food availability and energetic carrying capacity for waterbirds in the Great Salt Lake wetlands. Poster presentation, 4th North American Duck Symposium, Bismarck ND.
2005. Uyehara, K. J., Engilis, A., Jr., and **B. D. Dugger**. Wetland Features Influencing Koloa Occupancy on Agricultural Lands, Island of Hawai'i. Hawai'i Conservation Alliance Annual Conference. Honolulu, HI, July 27-29, 2005.
2005. **Dugger, B. D.**, M. J. Petrie, T. Mayer, and D. Mauser. Modeling alternate Wetland

- management scenarios to provide habitat for non-breeding waterfowl in the face of water supply shortages in the western United states. Presentation. Pacific Flyway Symposium, Newport, OR, March.
2005. Ivey, G., and **B. D. Dugger**. Factors influencing survival of Greater Sandhill Cranes nests at Malheur National Wildlife Refuge. Presentation. Joint Meeting The Waterbird Society and the Pacific Seabird Group, Portland OR, Jan 2005.
2005. E. Elliot-Smith, **B. D. Dugger**, and J. Nawrot. Influence of mudflat width on shorebird foraging behavior on an inland reservoir. Presentation, Joint Meeting The Waterbird Society and the Pacific Seabird Group, Portland OR, Jan 2005.
2005. Value of reservoirs as habitat for migrating shorebirds. E. Elliot-Smith, **B. D. Dugger**, and J. Nawrot. Poster. Joint Meeting The Waterbird Society and the Pacific Seabird Group, Portland OR, Jan 2005.
2005. Finger, R. S., **B. D. Dugger**, M. J. Petrie, and D. Mauser. Availability and winter depletion of submerged aquatic vegetation on Lower Klamath and Tule Lake National Wildlife Refuges. Poster. Joint Meeting The Waterbird Society and the Pacific Seabird Group, Portland OR, Jan 2005.
2005. Greer, A. K., **B. D. Dugger**, D. G. Graber, and M. J. Petrie. Influence of wetland hydroperiod on food availability for spring migrating waterfowl. Poster. Joint Meeting The Waterbird Society and the Pacific Seabird Group, Portland OR, Jan 2005.
2005. Rutka, D. M., **B. D. Dugger**, K. J. Reinecke, and M. J. Petrie. Behavioral response of wintering waterfowl to waste rice depletion in the Mississippi Alluvial Valley. Poster. Joint Meeting The Waterbird Society and the Pacific Seabird Group, Portland OR, Jan 2005.
2004. **Dugger, B. D.** Winter Ecology and Management of Canada Geese in North America. (*Invited*) International Symposium on Conservation of Migratory Birds. Seoul, South Korea.
2003. **Dugger, B. D.**, D. Mauser, M. J. Petrie, and T. Mayer. Conservation planning for arid wetland regions in the intermountain west. Verbal presentation at 3rd North American Duck Symposium, Sacramento, CA.
2003. Greer, A. K., **B. D. Dugger**, D. Graber, M. J. Petrie. Influence of fall vs. spring flooding on the availability of seed resources to spring migrating waterfowl. Verbal presentation at 3rd North American Duck Symposium, Sacramento, CA.
2003. Rutka, D. M., **B. Dugger**, K. J. Reinecke, and M. J. Petrie. Waste rice depletion by wintering waterfowl in the Mississippi Alluvial Valley. Verbal presentation at 3rd North American Duck Symposium, Sacramento, CA.
2003. Babineau, F. B., **B. D. Dugger**, D. Holm, and A. Woolf. 2003. Winter distribution and habitat use of swans in Illinois. Presentation at 19th Trumpeter Swan Society meeting.
2003. Babineau, F. M., **B. D. Dugger**, and A. Woolf. 2003. Daily movements and habitat use by trumpeter swans wintering in southern Illinois. Presented at 10th Annual Wildlife Society Conference.
2003. Cline, M. L., **B. D. Dugger**, C. R. Paine, J. D. Thompson, R. A. Montgomery, and K. M. Dugger. 2003. Factors affecting productivity of giant Canada geese (*Branta canadensis maxima*) in northeastern Illinois. International Canada Goose Symposium, Madison, WI.
2003. Paine, C. R., J. D. Thompson, R. A. Montgomery, M. L. Cline, and **B. D. Dugger**. 2003. Resident Canada goose flock demography in the Chicago metro-region. Paper presented at 10th Annual Wildlife Society Conference.
2003. Rutka, D. M., **B. Dugger**, K. J. Reinecke, and M. J. Petrie. Foraging patterns of waterfowl in rice fields of the Mississippi Alluvial Valley. Poster presented at 3rd North American

- Duck Symposium, Sacramento, CA.
2003. Reishus, B. S., **B. D. Dugger**, and T. Yerkes. Factors Influencing Female Mallard Home Range Size in the Great Lakes Region. Poster presentation at 3rd North American Duck Symposium, Sacramento, CA.
2003. Finger, R. S., **B. D. Dugger**, D. Mauser, and M. J. Petrie. Forage resources and winter depletion on Lower Klamath and Tule Lake National Wildlife Refuges. Poster presentation at 3rd North American Duck Symposium, Sacramento, CA.
2002. **Dugger, B. D.**, and D. Forsythe. Sex and Geographic Variation in Body Size of Long-billed Curlews. Poster presented at 3rd North American Ornithological Congress, New Orleans, LA. Sept. 24-29.
2002. **Dugger, B. D.** (*Invited*) Estimating Available Plant Food Resources for Waterfowl on Tule Lake – Lower Klamath NWR. Workshop on Conservation Planning for Waterbirds in the Klamath Basin. Sept. 16-18.
2002. Rutka, D., **B. D. Dugger**, K. J. Reinecke, and M. J. Petrie 2002. Waste Rice Depletion by Wintering Waterfowl in the Mississippi Alluvial Valley. 6th Annual Wildlife Society meeting, Bismark, N.D. Sept. 24-29.
2002. **Dugger, B. D.** Evaluation of Water Level Management as a Tool for Waterfowl and Fish Habitat Production on a Regulated River. Oregon Chapter TWS meeting.
2002. **Dugger, B. D.** A River Used to Run Through It: Ecological Restoration of Florida's Kissimmee. OSU Swamp Things Meeting.
2001. Sheehan, R.J., **B. D. Dugger**, B. M. Burr, S. R. Adams, and J. C. Feddersen. (*Invited*) Biological responses to pool-level management, Pool 25. Presented at the Upper Mississippi River Basin Association Meeting, Davenport, Iowa, 15 May.
2000. Feddersen, J. C. and **B. D. Dugger**. Evaluation of moist soil management practices on a large regulated river. – National Meeting of The Wildlife Society. Nashville, TN.
2000. Feddersen, J. C. and **B. D. Dugger**. Evaluation of Environmental Pool Management as a tool for waterfowl habitat production on the Upper Mississippi River. 62nd Midwest Fish and Wildlife Conference, Minneapolis, MN.
2000. **Dugger, B. D.**, R. Finger, and S. L. Melvin. Nest site characteristics of Mottled Ducks. 2nd North American Duck Symposium. Saskatoon, SK.
1999. **Dugger, B. D.**, Reproductive Ecology of a semi-tropical duck, the Mottled Duck. VI Neotropical Ornithological Congress, Monterrey, MX.
1999. **Dugger, B. D.**, S. L. Melvin, and R. Finger. Reproductive Ecology of Mottled Ducks in Florida. 117th American Ornithologist Meeting, Ithaca, NY. (poster)
1999. Feddersen, J. C. and **B. D. Dugger**. Community composition and seed production by moist-soil plants responding to water level manipulation on pool 25, Mississippi River. Upper Mississippi River Conservation Committee Mississippi River Vegetation Symposium. LaCrosse, WI.(poster)
1999. **Dugger, B. D.** Environmental conditions and there impact on wetland wildlife in the former Soviet Union. Southern Illinois University Chapter of the Wildlife Society.
1998. Anderson, D. H. and **B. D. Dugger**. A conceptual basis for evaluating restoration success. 63rd. North Am. Wildlife and Nat. Res. Conference, Orlando, FL.
1998. Ryan, M. R. and **B. D. Dugger**. Audio tapes vs. computer software for studying bird songs: the value of active learning. Second Annual Natural Resources Education Conference. Logan, UT.
1997. **Dugger, B. D.** and M. J. Petrie. Macro habitat comparisons of female Mallard time-

- activity budgets: a test of the Nutrient Limitation Hypothesis for clutch size in waterfowl. 115th Annual American Ornithologist Union Conference. Minneapolis, MN.
1997. **Dugger, B. D.** Use of waterfowl to evaluate river floodplain restoration success. Kissimmee River restoration evaluation workshop. West Palm Beach, FL.
1997. Dugger, K. M., **B. D. Dugger** (*presenter*), and L. H. Fredrickson. Annual survival of southern breeding female Hooded Mergansers. First North American Duck Symposium. Baton Rouge, LA.
1995. **Dugger, B. D.** Fitness consequences of brood parasitism to host female pochard and tufted duck. Delta Waterfowl Station, Delta, Manitoba.
1995. Ryan, M., P. Mayer, B. Root, and **B. D. Dugger** (*presenter*). Evidence for density-dependent reproduction in Piping plovers. 113th Annual American Ornithologist Union Conference. Cincinnati, Ohio.
1994. **Dugger, B. D.**, L. H. Fredrickson, and P. B. Blums. Impact of conspecific brood parasitism on host fitness for 2 species of waterfowl. 112th North American Ornithological Conference, Univ. of Montana, Missoula.
1993. **Dugger, B. D.** Late winter survival of female mallards in Arkansas. 55th Midwest Fish and Wildlife Conference, St. Louis, MO.
1991. **Dugger, B. D.** Waterfowl conservation in the United States. (*Invited*) Latvian Academy of Sciences.
1991. **Dugger, B. D.** Waterfowl management in Latvia. Missouri Fish and Wildlife Conference, Camdenton, MO.
1990. **Dugger, B. D.**, K. J. Reinecke, and L. H. Fredrickson. Habitat use by female Mallards in Arkansas. 50th Midwest Fish & Wildl. Conf., Minneapolis, MN.
-

HONORS/AWARDS

- 2013 – Student Learning and Success Teamwork Award, Oregon State University
- 2012 - voted an Elective Member to the American Ornithologists Union
- 2005 - 2010: Mace Assistant Professor of Watchable Wildlife
- 2004 - Best poster award: Texas Chapter of The Wildlife Society Annual Meeting (student D. Rutka first author)
- 1994 - American Ornithologist Union Travel Award to attend XXI International Ornithological Congress in Vienna, Austria.
- 1991 - Outstanding Graduate Student Teaching Award, University of Missouri, Columbia, MO.
- 1982 - University of California, Undergraduate Academic Scholarship.

SELECT PROFESSIONAL SERVICE

At Oregon State University

2011. Member, Provosts Ecampus Task Force
2010. Chair, OSU Athletic Advisory Committee
2011. OSU representative to the Commission on Intercollegiate Athletics
- 2009-2011. Member, OSU Faculty Senate Distance Education Committee, Chair in 2010, 2011
- 2010 –present. Member, OSU's Athletics Committee on Admissions

Other professional service

2013. co-Chair, special symposium on habitat carrying capacity and wintering waterfowl at

- Ecology and Conservation of North American Waterfowl Conference, Memphis, TN, January.
2013. Student Awards Committee, Ecology and Conservation of North American Waterfowl Conference, Memphis, TN, January.
- 2012 – present. Member, Science Advisory Panel, Intermountain West Joint Venture
- 2012 – consultant for National Science Support Team, North American Waterfowl Management Plan.
2010. Co-chair of Steering Committee and Science Program Committee, 2011 North American Arctic Goose Conference.
- 2009 – present. Member FW Curriculum Committee. Co-Chair since 2010.
- 2008-present. Associate Editor, Wildfowl
- 2007-2009. Associate Editor, Journal of Wildlife Management
- 2007-2008. Steering committee member, joint meeting of American Ornithologist Union (125th Anniversary), Cooper Ornithological Society, and Society of Canadian Ornithologists.
- 2005-present. Created and co-organize the Avian Ecology Study Group (AVES)
2005. Chair, Search Committee for Wildlife Agroecologist faculty position, Department of Fisheries & Wildlife, Oregon State University
- 2005-present. Co-chair Waterfowl Technical Committee, Pacific Coast Joint Venture
2003. Member Scientific Program Committee, 3rd North American Duck Symposium, Sacramento, CA.
2003. Judge for best student presentations, 3rd North American Duck Symposium, Sacramento, CA.
- 2003-2005. Board of Directors, Oregon Chapter of The Wildlife Society
- 2002-2004. Chair, Mewaldt-King Student Research Award Committee for the Cooper Ornithological Society.
- 2002-2005. Western Section Rep., University Education Working Group for National Chapter of The Wildlife Society.
- 2000-present. Founding member International Recovery Team for Brazilian Mergansers under IUCN's Threatened and Endangered Waterfowl Specialist Group.
2000. Steering Committee Member for annual meeting of Illinois Chapter of Wildlife Society
2000. EPA Star grant in Zoology review panel, Washington DC.
- 1998-2000. Technical Advisor for Illinois Department of Natural Resources Waterfowl Harvest Regulation Committee.

Journal Referee or panel reviewer (since 2000)

National Science Foundation, EPA Star Fellowship Program, , Auk, Avian Conservation and Ecology, Biological Conservation, Bird Populations, British Journal of Ecology, Condor, Ethology, Ibis, Journal of Animal Ecology, Journal of Wildlife Management, Journal of Field Ornithology, Journal Avian Biology, Northwest Science, Waterbirds, Wetlands, Wildlife Society Bulletin, Wilson Bulletin, Wildfowl.

PROFESSIONAL SOCIETIES

American Ornithologists Union, 1988 - present
 The Wildlife Society, 1990 - present
 Cooper Ornithological Society, 1987 - present
 Wilson Ornithological Society, 1988 - present
 IUCN's Duck Specialist Group and Threatened Waterfowl Species Group, 1997 - present

The Waterbird Society 2005 - present
Society of Wetland Scientists (1989 - 95)

Attachment F
Comments of the Conservation Organizations

On the Draft Environmental Impact Statement
St. Johns Bayou New Madrid Floodway Project (July 2013)



Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley

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February 2009

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ECOSYSTEM SERVICES SERIES



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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 (CH₄) and nitrous oxide (N₂O) 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 Ribaudó 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 Ribaudó 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 through 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 :

$$V = V(a) \quad [1]$$

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

$$S = S(a) \quad [2]$$

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:

$$V(S) = p \cdot S_M + v \cdot S_C + w \cdot S_P \quad [3]$$

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:

$$H_0: V_w(a) > V_A(a) \quad [4]$$

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 $V_A(a)$ 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.

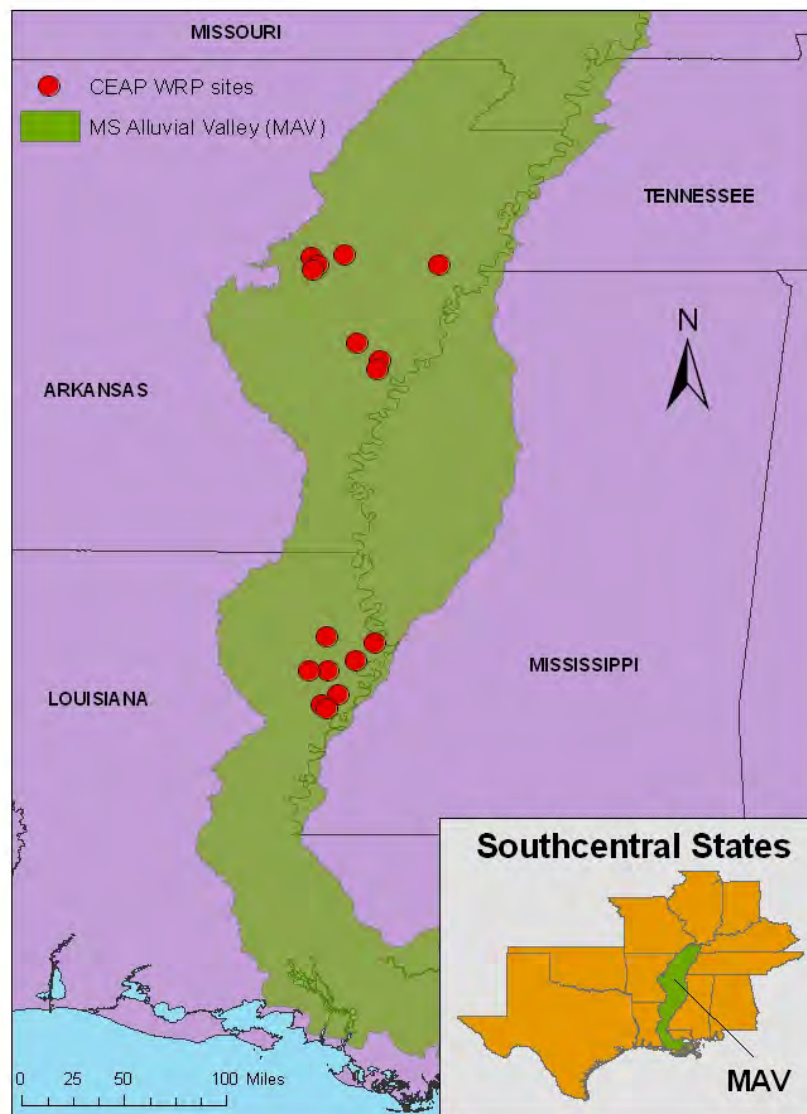
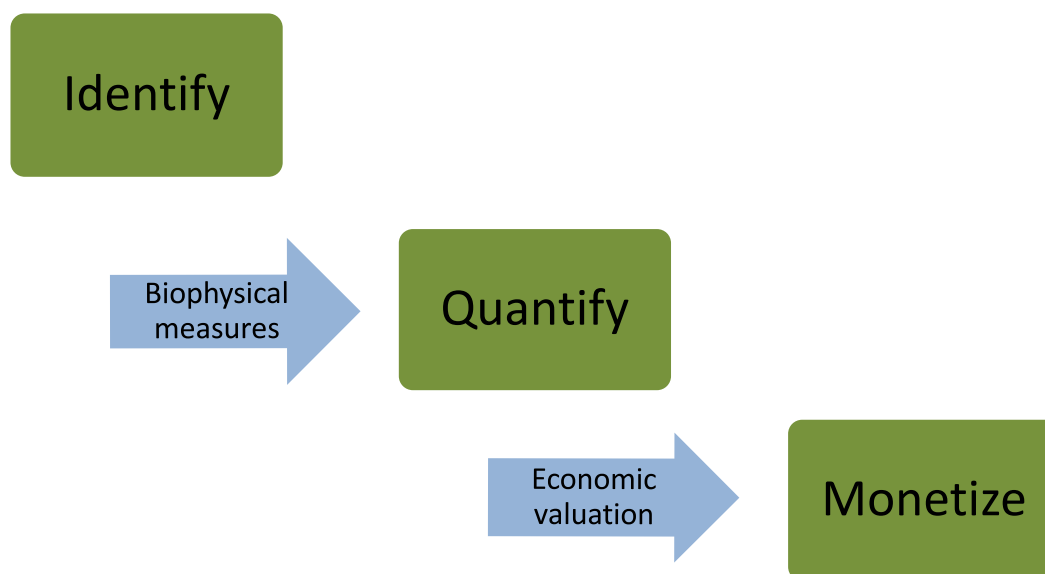


Figure 2. Flow chart of ecosystem service valuation process.



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 N₂O 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 ₂ e/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 (CO₂), 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-CO₂ trace GHGs such as nitrous oxide (N₂O) and methane (CH₄), gases that are individually more potent than CO₂. 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-CO₂ 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 Mg¹ 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 10⁶ grams. This paper uses Mg except in the context of the carbon credit trading market, in which the standard abbreviation *tCO₂e* is used to refer to “metric tons of CO₂ 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 et 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).

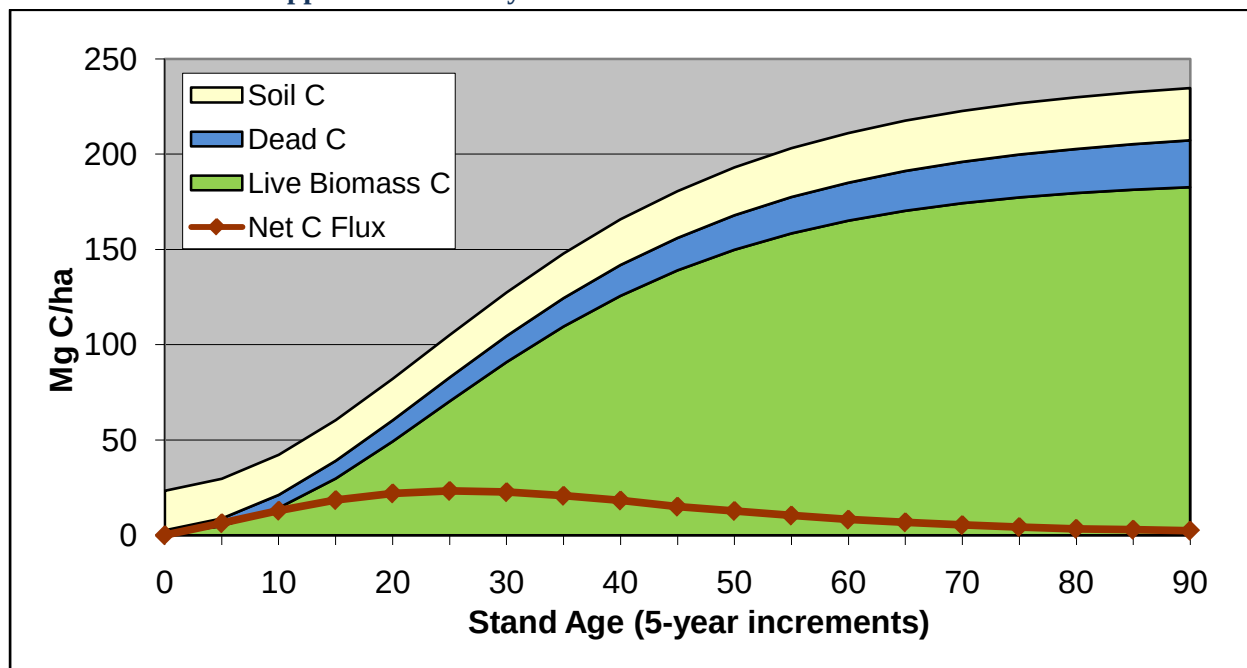
The majority of carbon sequestration potential resides in the growth of live carbon biomass (e.g., trees) through time, increasing from 72% at year 10 to over 86% in year 90 according to the USFS FORCARB2 tables (Smith et al. 2006). We estimate the carbon accumulation flows of this pool using the growth 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 CO₂ 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 (CO₂e) by simply multiplying by 3.67. CO₂e is the currency in which carbon service flows are monetized.

Non-CO₂ GHG emissions

The last step in quantifying the GHG sequestration potential is to account for the effect of emissions of trace GHGs, methane (CH₄), and nitrous oxide (N₂O). They have global warming potentials (GWP) much greater than CO₂ itself: 23 for CH₄ and 296 for N₂O (IPCC 2007). Both crop and wetland sites are net sources of CH₄ and N₂O emissions, though of different magnitudes. Accordingly, site N₂O and CH₄

fluxes are converted to their CO₂ equivalents using the GWP above, and are then subtracted from the CO₂ flux to determine the net GHG flux (MgCO₂e/ha/yr).²

For the agricultural sites in the region, CH₄ is emitted through rice production and residue burning and N₂O 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 CH₄ and N₂O emissions from the FASOMGHG model (Adams et al. 2005). Finally, weighted averages for the three MAV states are produced: -5.51 MgCO₂e /ha/5 years for CH₄ and -3.14 MgCO₂e /ha/5 years for N₂O.

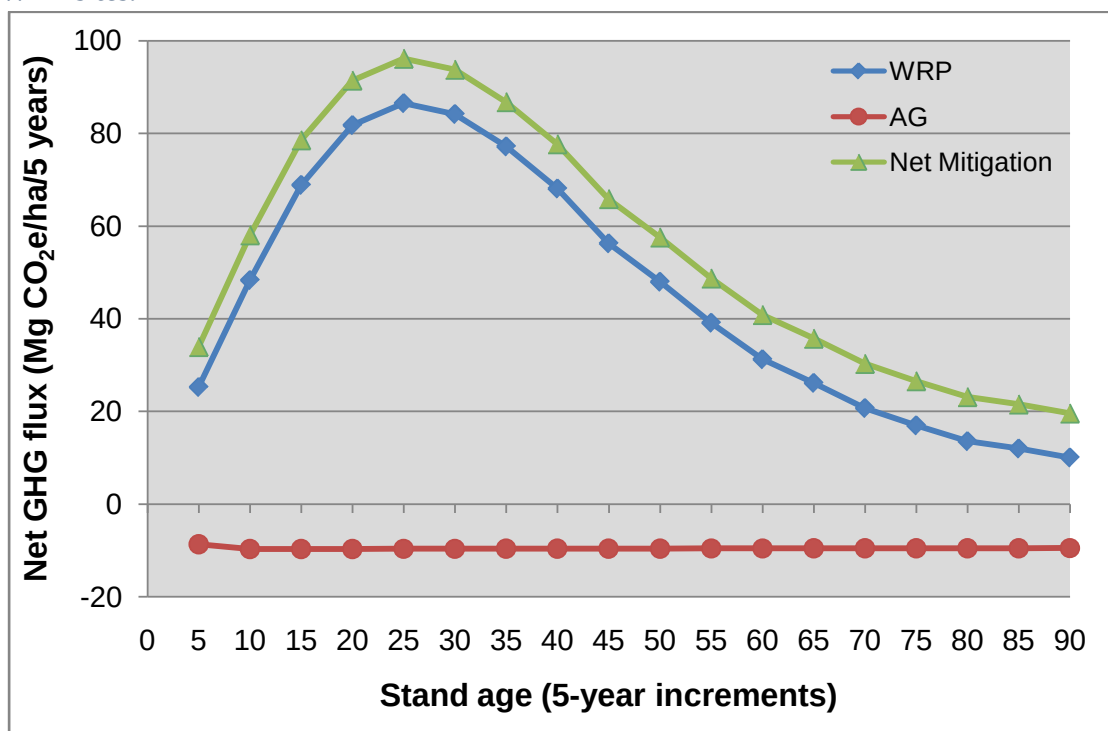
For both WRP and natural wetland sites, the levels of CH₄ and N₂O emissions vary by landscape position, i.e., whether the site is located in a low- or high-elevation position. Low-elevation sites flood more frequently and for longer duration than high-elevation sites and thus will experience longer periods 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 (N₂) and nitrous oxide (N₂O) (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 CH₄ and N₂O emission rates for each landscape position by the corresponding proportion (0.8/0.2) and generate a weighted average of CH₄ and N₂O emissions for each 5-year increment between years 5 and 90 after the wetlands restoration. After converting to MgCO₂ equivalents, the mean CH₄ flux is -0.13 MgCO₂e/ha/5 years and the mean N₂O flux was -2.02 MgCO₂e/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 CO₂ per hectare per 5-year period. Although non-CO₂ 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 CO₂e/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 CO₂ from oxidized soil carbon or the release of N₂O 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.



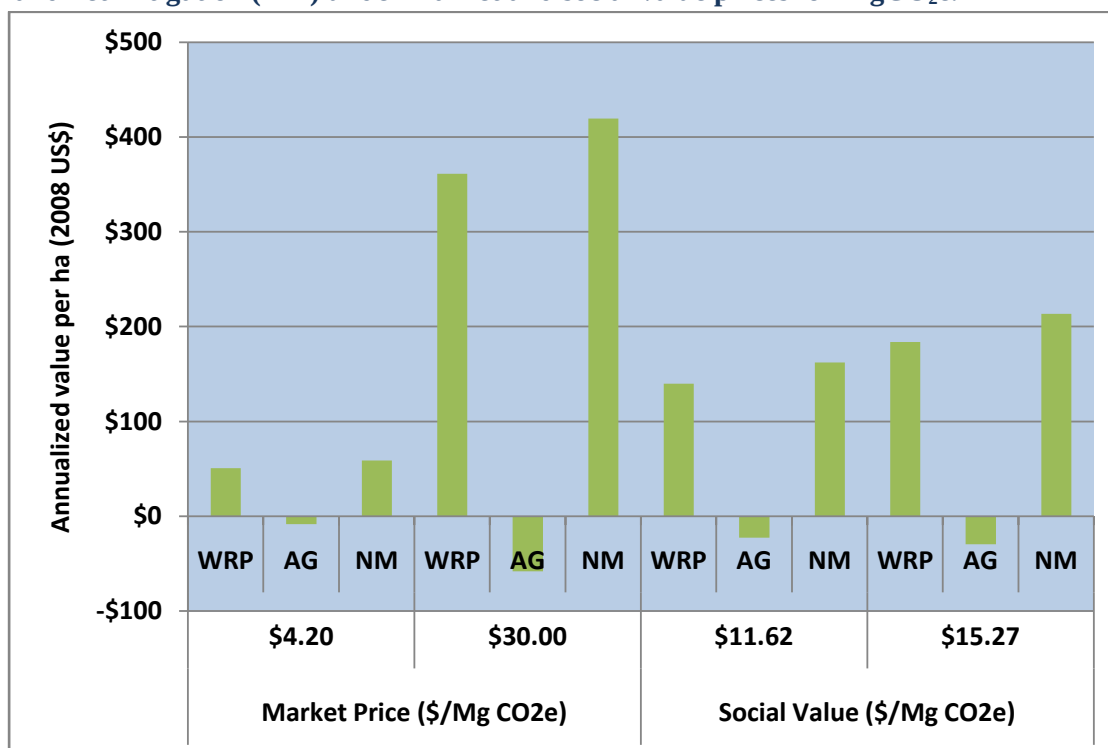
Monetizing GHG mitigation

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/MgCO₂ to \$15/MgCO₂. 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 MgCO₂e.



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 (NO₃) 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.

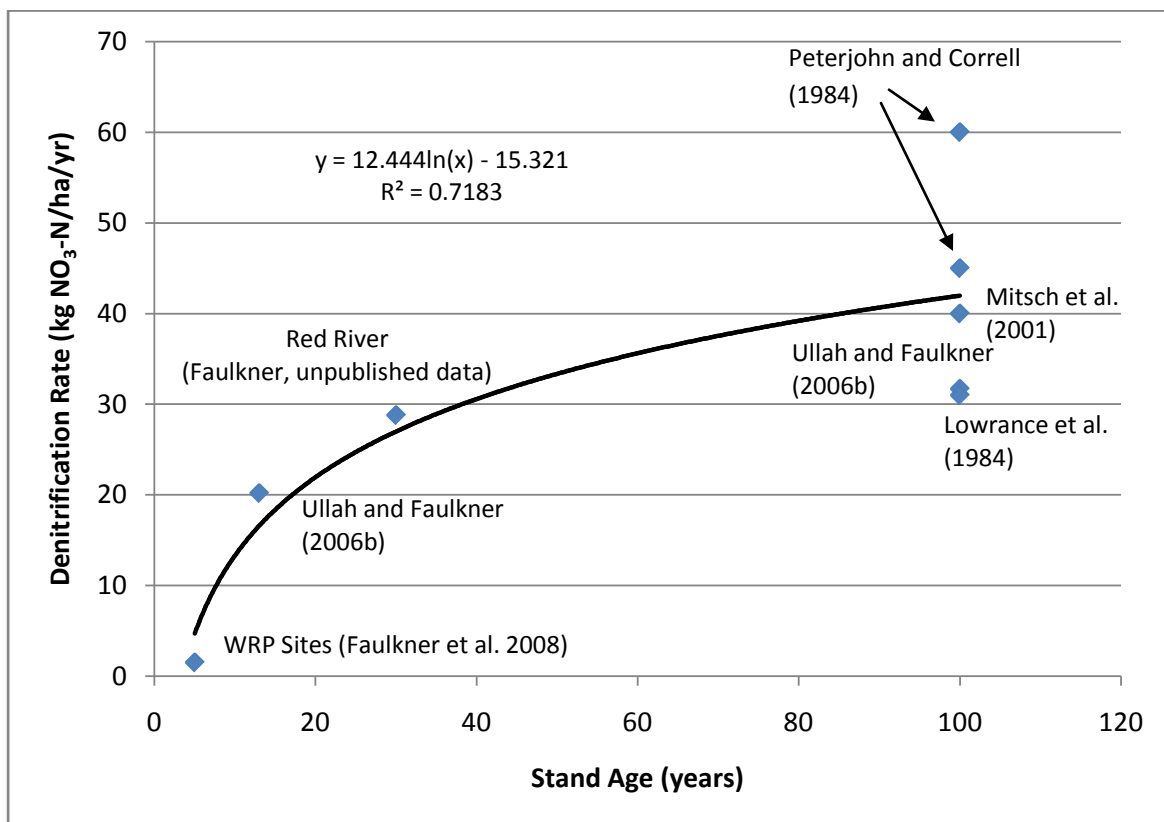
Crop Type	Estimated NO ₃ Loss	Crop Type	Crop Contribution
	kg/ha	Proportion	kg/ha
Corn	24.9	0.031	0.8
Cotton	29.4	0.1	2.9
Rice	69.9	0.32	22.4
Sorghum	13.1	0.005	0.1
Soy	29.0	0.516	15.0
Winter Wheat	5.7	0.028	0.2
Total			41.3

The second mitigation pathway is the removal of nitrate (NO₃) 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 NO₃/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.

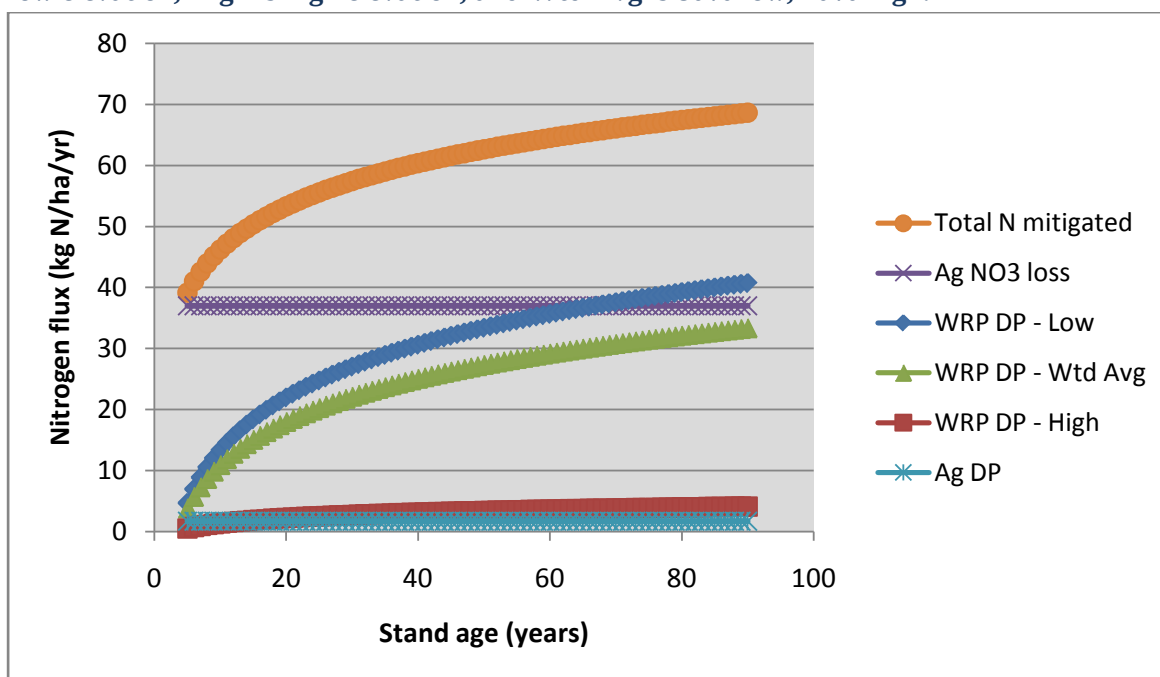


Figure 7 depicts the curves of denitrification rates for WRP low, high, weighted average, as well as for agriculture sites; the N losses associated with crop production; and the total N mitigated. Total N abatement is dominated by the cropland N loss pathway in the years immediately after a wetland restoration 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 Ribaud 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.

Ribaud 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, Ribaud 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 Ribaud 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 Ribaud 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/tCO₂e. We use the midpoint of this range, \$4.20/tCO₂e, 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/tCO₂e 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/tCO₂e to \$30/tCO₂e. 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 (Ribaud 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

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

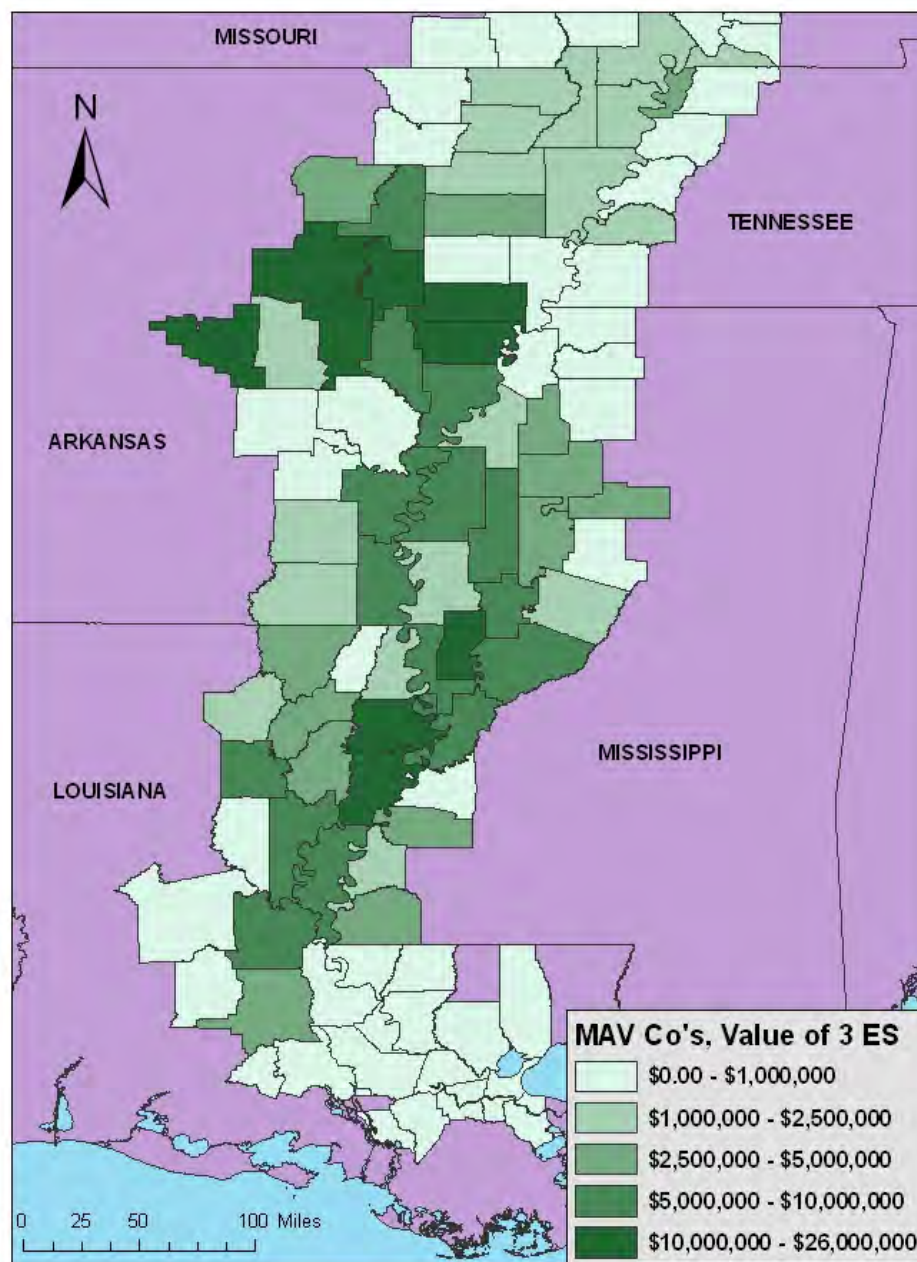
The measurement of aggregate benefits resulting from a program can be useful to policymakers by providing an estimate of the magnitude of program impacts. Using the per-hectare values for the three focal ecosystem services, we can scale them up to generate aggregate values for the study area, the three 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/tCO₂e), \$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.

REFERENCES

- Adams, D., R. Alig, et al. (2005). FASOMGHG Conceptual Structure and Specification: Documentation.
- Ahearn, M. C., K. C. Boyle, et al. (2006). Designing a CV study to estimate the benefits of the CRP on grassland bird populations. *Handbook on Contingent Valuation*. A. Alberini, Kahn, J. R. Northampton, Massachusetts, USA, Edward Elgar Publishing: 204-231.
- Anderson, J. D. and G. M. Parkhurst (2004). Economic comparison of commodity and conservation program benefits: An example from the Mississippi Delta. *Journal of Agricultural and Applied Economics* 36(2): 415–24.
- Barbier, E. B. (2007). Valuing ecosystem services as productive inputs. *Economic Policy*(49): 178–229.
- Batt, B. D. J., M. G. Anderson, et al. (1989). The use of prairie potholes by North American ducks. *Northern Prairie Wetlands*. A. G. van der Valk. Ames, Iowa, Iowa State University Press: 204–227.
- Brander, L. M., R. Florax, et al. (2006). The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature. *Environmental & Resource Economics* 33(2): 223–250.
- Carpenter, S. R., N. F. Caraco, et al. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications* 8(3): 559–568.
- Carson, R. T., R. C. Mitchell, et al. (1994). Contingent valuation and lost passive use: Damages from the Exxon Valdez. *Discussion Paper 94-18*. R. f. t. Future. Washington, D.C.
- Chan, K. M. A., R. M. Shaw, et al. (2006). Conservation planning for ecosystem services. *PLoS Biology* 4(11): 1–15.
- Chicago Climate Exchange (2007). FAQs: CCX Afforestation Offsets.
- Clement, J. C., G. Pinay, et al. (2002). Seasonal dynamics of denitrification along topohydrosequences in three different riparian wetlands. *Journal of Environmental Quality* 31(3): 1025–1037.
- Costanza, R., R. d’Arge, et al. (1997). The value of the world’s ecosystem services and natural capital. *Nature* 387(6630): 253–260.
- Daily, G. C., Ed. (1997). *Nature’s Services: Societal Dependence on Natural Ecosystems*. Washington, D.C., Island Press.
- Duffield, J. and C. Neher (1991). Montana waterfowl hunting: A contingent valuation assessment of economic benefits to hunters, Montana Department of Fish, Wildlife and Parks: 43.
- Duriancik, L. F., D. Bucks, et al. (2008). The first five years of the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation* 63(6): 185A–188A.
- Faulkner, S. P., W. Barrow, et al. (2008). Assessment Of Ecological Services Derived From U.S. Department of Agriculture Conservation Programs in the Mississippi Alluvial Valley: Regional Estimates and Functional Condition Indicator Models. Interim Report. Washington, D.C., USDA NRCS.

- Faulkner, S. P. and C. J. Richardson (1989). Physical and chemical characteristics of freshwater wetland soils. *Constructed Wetlands for Wastewater Treatment*. D. A. Hammer. Chelsea, Michigan, USA, Lewis Publishers, Inc.: 41–72.
- Feather, P. and D. Hellerstein (1997). Calibrating benefit function transfer to assess the Conservation Reserve Program. *American Journal of Agricultural Economics* 79(1): 151–62.
- Freeman III, M. A. (2003). Economic Valuation: What and Why. *A Primer on Nonmarket Valuation*. P. A. Champ, Boyle, K. J., Brown, T. C. Dordrecht, The Netherlands, Kluwer Academic Publishers: 1–26.
- Gan, C. and E. J. Luzar (1993). A conjoint analysis of waterfowl hunting in Louisiana. *Journal of Agricultural and Applied Economics* 25(2): 36–45.
- Goolsby, D. A. and W. A. Battaglin (2001). Long-term changes in concentrations and flux of nitrogen in the Mississippi River Basin, USA. *Hydrological Processes* 15(7): 1209–1226.
- Groffman, P. M. and J. M. Tiedje (1989). Denitrification in north temperate forest soils – spatial and temporal patterns at the landscape and seasonal scales. *Soil Biology & Biochemistry* 21(5): 613–620.
- Harriss, R. C., D. I. Sebach, et al. (1982). Methane flux in the great dismal swamp. *Nature* 297(5868): 673–674.
- Heal, G. (2000). Nature and the marketplace: Capturing the value of ecosystem services. Washington, D.C., Island Press.
- Howarth, R. B. and S. Farber (2002). Accounting for the value of ecosystem services. *Ecological Economics* 41(3): 421–429.
- Hunter, R. G. and S. P. Faulkner (2001). Denitrification potentials in restored and natural bottomland hardwood wetlands. *Soil Science Society of America Journal* 65(6): 1865–1872.
- Hussain, A., I. A. Munn, et al. (2007). Hedonic analysis of hunting lease revenue and landowner willingness to provide fee-access hunting. *Forest Science* 53(4): 493–506.
- Ibendahl, G. (2004). Risk-adjusted comparison of Conservation Reserve Program versus payments for a corn-soybean farmer. *Journal of Agricultural and Applied Economics* 36(2): 425–434.
- Ibendahl, G. (2008). An accounting tradeoff between WRP and government payments. *Southern Agricultural Economics Association Annual Meeting*. Dallas, TX: 16.
- IPCC (2007). Climate Change 2007: Impacts, Adaptation, and Vulnerability. Fourth Assessment Report, Working Group II, Intergovernmental Panel on Climate Change.
- James, J. D., T. E. Moorman, et al. (In review). Contribution of the Wetlands Reserve Program to waterfowl foraging habitat goals in the Mississippi Alluvial Valley. *Wetlands*.
- King, S. L., D. J. Twedt, et al. (2006). The role of the Wetland Reserve Program in conservation efforts in the Mississippi River Alluvial Valley. *Wildlife Society Bulletin* 34(4): 914–920.
- Kramer, R. A. (2007). Economic Valuation of Ecosystem Services. *Sage Handbook on Environment and Society*. e. a. Jules Pretty. London, UK, Sage Publications Ltd: 172–180.

- Krutilla, J. V. (1967). Conservation reconsidered. *American Economic Review*(57): 777–86.
- Loomis, J., P. Kent, et al. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: Results from a contingent valuation survey. *Ecological Economics* 33(1): 103–117.
- Lower Mississippi Valley Joint Venture (LMVJV) Waterfowl Working Group (2007). Report to the Management Board – June 2007: 55.
- Lowrance, R., R. Todd, et al. (1984). Riparian forests as nutrient filters in agricultural watersheds. *BioScience* 34(6): 374–377.
- Lowrance, R. R., Isenhardt, T.M., Gburek, W., Shields Jr., F.D., Wigington Jr., P.J., Dabney, S.M. (2006). Landscape management practices. *Environmental Benefits of Conservation on Cropland: The Status of Our Knowledge*. M. Schnepf, Cox, C. Ankeny, Iowa, USA, Soil and Water Conservation Society.
- Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being: Synthesis*.
- Mississippi River/Gulf of Mexico Water Nutrient Task Force (2007). Gulf Hypoxia Action Plan 2008, Mississippi River/Gulf of Mexico Water Nutrient Task Force.
- Mitsch, W. J., J. W. Day, et al. (2001). Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to counter a persistent ecological problem. *BioScience* 51(5): 373–388.
- Mitsch, W. J. and J. G. Gosselink (2007). *Wetlands*. Hoboken, NJ, John Wiley & Sons.
- Morgan, C. and A. Wolverton (2005). Water Quality Trading in the United States. Washington, D.C., U.S. Environmental Protection Agency, National Center for Environmental Economics: 51.
- Murray, B. C., B. A. McCarl, et al. (2004). Estimating leakage from forest carbon sequestration programs. *Land Economics* 80(1): 109–124.
- Murray, B. C., B. Sohngen, et al. (2007). Economic consequences of consideration of permanence, leakage and additionality for soil carbon sequestration projects. *Climatic Change* 80(1-2): 127–143.
- National Research Council (2005). Valuing Ecosystem Services: Toward Better Environmental Decision-Making. Washington, D.C.
- Novak, J. M., K. C. Stone, et al. (2004). Dissolved phosphorus retention and release from a coastal plain in-stream wetland. *Journal of Environmental Quality* 33(1): 394–401.
- Palmquist, R. B. (1989). Land as a differentiated factor of production – A hedonic model and its implications for welfare measurement. *Land Economics* 65(1): 23–28.
- Peterjohn, W. T. and D. L. Correll (1984). Nutrient dynamics in an agricultural watershed – Observations on the role of a riparian forest. *Ecology* 65(5): 1466–1475.
- Potter, S. R., S. Andrews, et al. (2006). Model Simulation of Soil Loss, Nutrient Loss, and Change in Soil Organic Carbon Associated with Crop Production, U.S. Department of Agriculture Natural Resources Conservation Service: 237.

- Potter, S. R., J. A. Atwood, et al. (2006). The National Nutrient Loss and Soil Carbon Database. *BRC Report*. Temple, TX, Texas Agriculture Experiment Station Blackland Research Center.
- Pulliam, W. M. (1993). Carbon dioxide and methane exports from a Southeastern floodplain swamp. *Ecological Monographs* 63(1): 29–53.
- Randall, A. (1991). Total and non-use values. *Measuring the Demand for Environmental Quality*. J. B. Braden, Kolstad, C. D. Amsterdam, Netherlands, North-Holland.
- Reddy, K. R., R. H. Kadlec, et al. (1999). Phosphorus retention in streams and wetlands: A review. *Critical Reviews in Environmental Science and Technology* 29(1): 83–146.
- Reineke, K. J. and R. M. Kaminski (2007). Lower Mississippi Valley Joint Venture, Unpubl. Waterfowl Working Group Memorandum. Vicksburg, MS, U.S. Fish and Wildlife Service.
- Rhyne, J. and I. A. Munn (2007). Factors Determining Per Acre Market Value of Hunting Leases on Sixteenth Section Lands in Mississippi. *Forest and Wildlife Research Center*, Mississippi State University: 7.
- Ribaudo, M. O., C. Greene, et al. (2008). The Use of Markets To Increase Private Investment in Environmental Stewardship. Washington, D.C., USDA Economic Research Service.
- Ribaudo, M. O., R. Heimlich, et al. (2001). Least-cost management of nonpoint source pollution: source reduction versus interception strategies for controlling nitrogen loss in the Mississippi Basin. *Ecological Economics* 37(2): 183–197.
- Ribaudo, M. O., R. Heimlich, et al. (2005). Nitrogen sources and Gulf hypoxia: potential for environmental credit trading. *Ecological Economics* 52(2): 159–168.
- Ricketts, T. H., G. C. Daily, et al. (2004). Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences of the United States of America* 101(34): 12579–12582.
- Rosen, S. (1974). Hedonic prices and implicit markets – product differentiation in pure competition. *Journal of Political Economy* 82(1): 34–55.
- Rosenberger, R. S. and J. B. Loomis (2001). Benefit transfer of outdoor recreation use values: A technical document supporting the Forest Service Strategic Plan (2000 revision). Fort Collins, CO, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 59.
- Rosenberger, R. S. and J. B. Loomis (2003). Benefit Transfer. *A Primer on Nonmarket Valuation*. P. A. Champ, Boyle, K. J., Brown, T. C. Dordrecht, The Netherlands, Kluwer Academic Publishers: 445–482.
- Rosenberger, R. S. and T. D. Stanley (2006). Measurement, generalization, and publication: Sources of error in benefit transfers and their management. *Ecological Economics* 60(2): 372–378.
- Shoch, D. T., G. Kaster, et al. (In review). Carbon sequestration potential of bottomland hardwood afforestation in the Lower Mississippi Valley, U.S.A. *Wetlands*.
- Smith, J. E., L. S. Heath, et al. (2006). Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States, U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 216.

- Toman, M. (1998). Special section: Forum on valuation of ecosystem services: Why not to calculate the value of the world's ecosystem services and natural capital. *Ecological Economics* 25(1): 57–60.
- Twedt, D. J. and C. R. Loesch (1999). Forest area and distribution in the Mississippi Alluvial Valley: implications for breeding bird conservation. *Journal of Biogeography* 26(6): 1215–1224.
- U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). Quick Stats, State and County Data. Retrieved August 26, 2008, from http://www.nass.usda.gov/QuickStats/Create_County_All.jsp.
- U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS) (2006). Land Values and Cash Rents 2006 Summary.
- U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) (2004). Part 514 – Wetland Reserve Program. *National Food Security Act Manual*. Washington, D.C., USA.
- U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS). (2007). Farm Bill 2002, Wetlands Reserve Program: Key Points. Retrieved June 6, 2008, from http://www.nrcs.usda.gov/Programs/WRP/2007_ContractInfo/2007WRPKeyPoints.pdf.
- U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS)a. CEAP National Assessment: Wetlands. Retrieved May 25, 2008, from <http://www.nrcs.usda.gov/Technical/nri/ceap/wetlands.html>.
- U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS)b. Wetland Reserve Program. Retrieved June 16, 2008, from <http://www.nrcs.usda.gov/Programs/WRP/>.
- U.S. Department of Labor – Bureau of Labor Statistics (BLS). CPI Inflation Calculator. Retrieved September 16, 2008, from <http://data.bls.gov/cgi-bin/cpicalc.pl>.
- U.S. Environmental Protection Agency (USEPA) (2002). A Framework for the Economic Assessment of Ecological Benefits.
- U.S. Fish and Wildlife Service. 2003. Migratory bird hunting activity and harvest during the 2001 and 2002 hunting seasons: Preliminary estimates. U.S. Department of the Interior, Washington, D.C. U.S.A.
- U.S. Fish and Wildlife Service. 2004. Migratory bird hunting activity and harvest during the 2002 and 2003 hunting seasons: Preliminary estimates. U.S. Department of the Interior, Washington, D.C. U.S.A.
- U.S. Fish and Wildlife Service. 2006. Migratory bird hunting activity and harvest during the 2004 and 2005 hunting seasons: Preliminary estimates. U.S. Department of the Interior, Washington, D.C. U.S.A.
- Ullah, S., G. A. Breitenbeck, et al. (2005). Denitrification and N₂O emission from forested and cultivated alluvial clay soil. *Biogeochemistry* 73(3): 499–513.
- Ullah, S. and S. P. Faulkner (2006). Denitrification potential of different land-use types in an agricultural watershed, Lower Mississippi Valley. *Ecological Engineering* 28(2): 131–140.
- Ullah, S. and S. P. Faulkner (2006). Use of cotton gin trash to enhance denitrification in restored forested wetlands. *Forest Ecology and Management* 237(1-3): 557–563.

- Williams, J. R., C. A. Jones, et al. (1989). The epic crop growth-model. *Transactions of the ASAE* 32(2): 497–511.
- Wilson, M. A. and J. P. Hoehn (2006). Valuing environmental goods and services using benefit transfer: The state-of-the art and science. *Ecological Economics* 60(2): 335–342.
- Woodward, R. T. and Y.-S. Wui (2001). The economic value of wetland services: A meta-analysis. *Ecological Economics* 37(2): 257–270.
- Wu, J. J. (2000). Slippage effects of the conservation reserve program. *American Journal of Agricultural Economics* 82(4): 979–992.
- Young, R. A. (2005). Deterring the economic value of water: Concepts and methods. Washington, D.C., RFF Press.
- Yu, K. W., S. P. Faulkner, et al. (2008). Effect of hydrological conditions on nitrous oxide, methane, and carbon dioxide dynamics in a bottomland hardwood forest and its implication for soil carbon sequestration. *Global Change Biology* 14(4): 798–812.

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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.

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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. Key Concepts

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 restoration 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 Daily 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

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
<i>Regulation Functions</i>		<i>Maintenance of essential ecological processes and life support systems</i>	
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

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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		<i>Providing habitat (suitable living space) for wild plant and animal species</i>	
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		<i>Provision of natural resources</i>	
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		<i>Providing opportunities for cognitive development</i>	
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

<i>Direct Use Values</i>	
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.
<i>Indirect Use Values</i>	
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

The Yazoo 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
<i>Wetland hardwood forests drained to non-jurisdictional</i>	18,000
<i>Wetlands, shrub and herbaceous drained to non-jurisdictional</i>	8,300
<i>Wetland hardwood forests negatively impacted</i>	27,900
<i>Wetlands, shrub and herbaceous negatively impacted</i>	12,800
<i>Total wetlands impacted</i>	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.

Ecosystem Service Valuation Analysis of Yazoo Wetlands

Ecological Service	Impacted Yazoo Wetland Forests		Impacted Yazoo Non-forested Wetlands	
	<i>Low</i>	<i>High</i>	<i>Low</i>	<i>High</i>
<i>Gas regulation</i>	\$21.11	\$191.87	\$29.43	\$267.53
<i>Climate regulation</i>	\$136.64	\$136.64	\$136.64	\$136.64
<i>Waste treatment</i>	\$3.13	\$1,069.56	\$3.13	\$1,069.56
<i>Water supply</i>	\$42.52	\$113.39	\$42.52	\$113.39
<i>Water regulation</i>	\$15.47	\$15.47	\$15.47	\$15.47
<i>Soil retention and formation</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Fisheries</i>	\$25.80	\$25.80	\$53.37	\$74.46
<i>Nutrient regulation</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Recreation</i>	\$134.44	\$134.44	\$134.44	\$134.44
<i>Pollination</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Biological control</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Refugium and Nursery function</i>	Not valued	Not Valued	\$185.51	\$442.67
<i>Food</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Raw materials</i>	Not valued	Not Valued	\$4.26	\$4.34
<i>Genetic resources</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Medical resources</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Ornamental resources</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Aesthetic information</i>	Not valued	Not Valued	\$68.09	\$217.79
<i>Cultural & artistic information</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Spiritual & historic information</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Science & education</i>	Not valued	Not Valued	Not valued	Not Valued
<i>Navigational services</i>	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.

References and Related Sources

- Adamowicz, W.L. (1991). Valuation of environmental amenities. *Canadian Journal of Agriculture Economics*, 39, 609-618.
- American Forests. (1998). *Regional ecosystem analysis Puget Sound metropolitan area: Calculation the value of nature*. Washington D.C., American Forests. Available at http://www.americanforests.org/downloads/rea/AF_PugetSound.pdf.
- Anderson, L.M. and Cordell, H.K. (1988). Influence of trees on residential property values in Athens, Georgia: A survey based on actual sales prices. *Landscape and Urban Planning* 15, 153-164.
- Antle J.M., and Capalbo, S.M. (2002). Agriculture as a managed ecosystem: Policy implications. *Journal Of Agricultural And Resource Economics*, 27(1), 1-15.
- Batabyal, A.A., Kahn, J.R., and O'Neill, R.V. (2003). On the scarcity value of ecosystem services. *Journal of Environmental Economics and Management*, 46, 334-352.
- Batie, S.S. and Wilson, J.R. (1978). Economic values attributable to Virginia's coastal wetlands as inputs in oyster production. *Southern Journal of Agricultural Economics*, 111-118.
- Batker, David. (2005). Supplemental Ecological Services Study: Tolt River Watershed Asset Management Plan. Seattle Public Utilities, Seattle, Washington
- Batker, D., Barclay, E., Boumans, R., and Hathaway, T. (2005). Ecosystem Services Enhanced by Salmon Habitat Conservation in the Green/Duwamish and Central Puget Sound Watershed. Prepared for WRIA 9 Steering Committee and King County DNRP by the Asia Pacific Environmental Exchange.
- Bingham, G., Bishop, R., Brody, M., Bromley, D., Clark, E., Cooper, W., Costanza, R., Hale, T., Hayden, G., Kellert, S., Norgaard, R., Norton, B., Payne, J., Russell, C., and G. Suter. (1995). Issues in ecosystem valuation: Improving information for decision making. *Ecological Economics* 14, 73-90.
- Bishop, J. and Landell-Mills, N. (2002). Forest Environmental Services: An Overview. In S. Pagiola, J. Bishop, and N. Landell-Mills (Eds.), *Selling forest environmental services*. Sterling, VA: Earthscan Publications Limited.
- Boumans, R., Costanza, R., Farley, J., Wilson, M., Rotmans, J., Villa, F., Porela, R., and M. Grasso. (2002). Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. *Ecological Economics* 41, 525-560.
- Bouwes, N.W. and Scheider, R. (1979). Procedures in estimating benefits of water quality change. *American Journal of Agricultural Economics*, 534-539.
- Blamey, R.K. (1996). Citizens, consumers, and contingent Valuation: Clarification and the expression of citizen values and issue-opinions. In W.L. Adamowicz et al (Eds.) *Forestry, Economics, and the Environment*. Wallingford : CAB International.
- Bolund, P., and Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics* 29, 293-301.

- Bowker, J.M., English, D.B., and Donovan, J.A. (1996). Toward a value for guided rafting on southern rivers. *Journal of Agricultural and Applied Economics* 28(2), 423-432.
- Brand, D. (2002). Investing in the environmental services of Australian forests. In Selling Forest Environmental services. In S. Pagiola, J. Bishop, and N. Landell-Mills (Eds.), *Selling forest environmental services*. Sterling, VA: Earthscan Publications Limited.
- Brown, R.S., and Marshall, K. (1996). Ecosystem management in state governments. *Ecological Applications*, 6(3), 721-723.
- Breunig, K. (2003). *Losing Ground: At What Cost? Technical Notes*. Boston: Mass Audubon.
- Cho, Y. (1990). *Willingness to pay for drinking water quality improvements: A contingent valuation study for southwestern Minnesota*. University of Minnesota graduate thesis.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M., (1997). The value of the world's ecosystem services and natural capital. *Nature* 387, 253-260.
- Crompton, J.L. (2001). The impact of parks and open space on property values and the property tax base. Ashburn, VA: National Recreation and Park Association. Retrieved June 1, 2004 from <http://rptsweb.tamu.edu/faculty/pubs/property%20value.pdf>.
- D'Arge, R.C., and Shogren, J. (1989). Okoboji experiment: Comparing non-market valuation techniques in an unusually well-defined market for water quality. *Ecological Economics* 1(1), 251-259.
- Daily, G.C. (Eds.). (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D.C.
- Daily, G.C., and Ellison, K. (2002). *The New Economy of Nature*. Washington, DC: Island Press.
- Daly, H.E., and Farley, J. (2004). *Ecological Economics: Principles and Applications*. Washington, DC: Island Press.
- Roy Darwin, R., Tsigas, M., Lewandrowski, J., and Raneses, A. (1996). Land use and cover in ecological economics. *Ecological Economics*, 17(3), 157-181.
- De Groot, R.S. (1992). *Functions of Nature: Evaluation of Nature in Environmental Planning, Management, and Decision Making*. Wolters-Noordhoff, Amsterdam.
- De Groot, R., van der Perk, J., Chiesura, A., and S. Marguliew. (2000). Ecological functions and socio-economic values of critical natural capital as a measure for ecological integrity and environmental health. In Crabbe, P., Holland, A., Ryszkowski, L., and L. Westra (Eds.), *Implementing ecological integrity: Restoring regional and global environmental and human health*. NATO-Science Series, IV. Earth and Environmental Sciences, I. Dordrecht/Boston/London: Kluwer Academic Publishers.
- De Groot, R.S., Wilson, M.A., and Boumans, R.M.J. (2002). A typology for the classification, description, and valuation of ecosystem functions, goods, and services. *Ecological Economics* 41, 393-408.
- Desvousges, W. H., Smith V.K., et al. (1987). Option price estimates for water quality improvements: a contingent valuation study for the Monongahela River. *Journal of Environmental Economics and Management* 14: 248-267.

- Desvougues, W.H., Johnson, F.R., and Banzhaf, H.S. (1998). *Environmental policy analysis with limited information: Principles and applications of the transfer method*. Northhampton, MA: Edward Elgar.
- Dolsak, N., and Ostrom, E. (2003). The challenges of the commons. Pp. 3-34. In N. Dolsak and E. Ostrom (Eds.) *The commons in the new millennium: challenges and adaptation*. Cambridge, MA: MIT Press.
- Dorfman, J. H., A. G. Keeler, and Kriesel, W. (1996). Valuing risk-reducing interventions with hedonic models: The case of erosion protection. *Journal of Agricultural and Resource Economics*, 21(1), 109-119.
- Dudley, N., and Stolton, S. (2003). *Running Pure: The Importance of Forest Protected Areas to Drinking Water*. World Bank/WWF Alliance for Forest Conservation and Sustainable Use. Retrieved June 1, 2004 from <http://www.panda.org/downloads/freshwater/runningpurereport.pdf>.
- Environmental Protection Agency. (n.d.). *Watershed Academy Training*. Author. Retrieved June 1, 2004 from <http://www.epa.gov/watertrain/>.
- FEMAT. (2004). Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. Report of the Forest Ecosystem Management Assessment Team Retrieved June 1, 2004 from <http://pnwin.nbii.gov/nwfp/FEMAT/>.
- Forest Outreach Network. (n.d.). *Home Page*. Author. Retrieved June 1, 2004 from <http://dnr.metrokc.gov/wlr/lands/forestry/FON.htm>.
- Farber, S., and Costanza, R. (1987). The economic value of wetlands systems. *Journal of Environmental Management* 24(1), 41-51.
- Farber, S., Costanza, R., and M. Wilson. (2002). Economic and ecological concepts for valuing ecosystem services. *Ecological Economics* 41, 375-392.
- Florida Department of Environmental Protection. (2004). *Preservation 2000/ Florida Forever Home Page*. Author. Available at <http://www.dep.state.fl.us/lands/acquisition/p2000/>.
- Freeman, A.M. III, (2003). *The measurement of environmental and resource values: Theory and methods* (2nd ed.). Washington, D.C: Resources for the Future.
- Geores, M.E. (2003). The relationship between resource definition and scale: Considering the forest. In N. Dolsak and E. Ostrom (Eds.), *The Commons in the New Millenium*. Cambridge, MA: MIT Press.
- Gibson, C.C., Ostrom, E., and McKean, M.A. (200). Forests, people, and governance: Some initial theoretical lessons. In C.C. Gibson, M.A. McKean, and E. Ostrom (Eds.), *People and Forests: Communities, Institutions, and Governance*, 227-242. Cambridge, MA: MIT Press.
- Haener, M.K., and Adamowicz, W.L. (2000). Regional forest resource accounting: A northern Alberta case study. *Canadian Journal of Forest Research*, 30(2), 264-273.
- Hardin, G. (1968). The tragedy of the commons. *Science*, 162, 1243-1248.
- Hawken, P. (1993). *The Ecology of Commerce*. New York: HarperCollins.
- Haynes, R.W., Monserud, R.A. (2002). *A basis for understanding compatibility among wood*

- production and other forest values*. Gen. Tech. Rep. PNW-GTR-529. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Heal, G. (2000). *Nature and the Marketplace: Capturing the Value of Ecosystem Services*. Washington, DC: Island Press.
- Howarth, R. and S. Farber. (2002). Accounting for the value of ecosystem services. *Ecological Economics* 41, 421-429.
- Jones, P.F., and Downey, B.L. (2004). Multi-species conservation value. In R.W. Quinlan, B.A. Downey, B.L. Downey and P.F. Jones (Eds.), *MULTISAR: The Milk River Basin Project, A Multi-Species Conservation Strategy For Species at Risk: Year 2-Progress Report*. Alberta Sustainable Resource Management, Fish and Wildlife Division, Alberta Species at Risk Report No. 87, Edmonton, AB. Retrieved June 1, 2004, from http://www3.gov.ab.ca/srd/fw/riskspecies/pdf/SAR_87.pdf.
- Kenyon, W., and Nevin, C. (2001). The use of economic and participatory approaches to assess forest development: a case study in the Ettrick Valley. *Forest Policy and Economics* 3(1-2), 69-80.
- King County Agriculture Program. (n.d.). [brochure]. King County Department of Natural Resources and Parks.
- King County Forestry Program. (n.d.). [brochure]. King County Department of Natural Resources and Parks.
- King County. (n.d.) *Public Benefit Rating System and Timber Land Program*. Retrieved June 1, 2004 from www.dnr.metrokc.gov/wlr/lands/incentiv.htm
- King County Department of Natural Resources Program. (2001). *Green River Flood Control Zone District 2001 Annual Report*. King County Department of Natural Resources and Parks, Water and Land Resources Division. Retrieved June 10, 2004 from <http://dnr.metrokc.gov/wlr/flood/GRFCZD.htm>.
- Lackey, Brent. (2004). *The Early Action Endangered Species Act (ESA) Response Program in the Tolt River Watershed; Powerpoint*. SPU Asset Management Committee Briefing, November 3, 2004.
- Laverne, R.J., and Winson-Geideman, K. (2003). The influence of trees and landscaping on rental rates at office buildings. *Journal of Arboriculture*, 29(5), 281–290.
- Leach, W.D., Pelkey, N.W., and Sabatier, P.A. (2002). Stakeholder partnerships as collaborative policymaking: Evaluation criteria applied to watershed management in California and Washington. *Journal of Policy Analysis and Management*, 21(4), 645-670.
- Limburg, K.E., O'Neill, R.V., Costanza, R., and Farber, S. (2002). Complex systems and valuation. *Ecological Economics*, 41(3), 409-420.
- Lippke, B. (1996). Incentives for managing landscapes to meet non-timber goals: Lessons from the Washington Landscape Management Project. In Adamowicz et al (Eds.) *Forestry, Economics, and the Environment*.
- May, P.H., Neto, F.V., Denardin, V., and Loureiro, W. (2002). Using fiscal instruments to encourage conservation: Municipal responses to the 'ecological' value-added tax in Parana and Minas Gerais, Brazil. In S. Pagiola, J. Bishop, and N. Landell-Mills (Eds.), *Selling forest environmental services*. Sterling, VA: Earthscan Publications Limited.

- McCarl, B.A., and Schneider, U.A. (2000). U.S. agriculture's role in a greenhouse gas emission mitigation world: An economic perspective. *Review of Agricultural Economics* 22, 134-159.
- McKean, M. (2000). Common property: What is it, what is it good for, and what makes it work? In C.C. Gibson, M.A. McKean, and E. Ostrom (Eds.) *People and Forests*. Cambridge, MA: MIT Press.
- McPherson, E.G., Simpson, J.R., and Scott, K.I. (1998). "Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models." *Atmospheric Environment* 32(1), 75-84.
- Nunes, P.A.L.D., van den Bergh, J.C.J.M., and Nijkamp, P. (2003). *The ecological economics of biodiversity*. Northampton, MA: Edward Elgar Publishing.
- Ostrom, E. (1997). *The comparative study of public economies*. Memphis, TN: P.K. Seidman Foundation, 1998.
- Pacheco, A.I., and Tyrrell, T.J. (2003). *The economic value of Narragansett Bay: A review of economic studies*. University of Rhode Island, Kingston, RI.
- Pagiola, S. (2002). Paying for water services in Central America: Learning from Costa Rica. In S. Pagiola, J. Bishop, and N. Landell-Mills (Eds.) *Selling Forest Environmental Services*. Sterling, VA: Earthscan Publications Limited.
- Pagiola, S., Landell-Mills, N., and Bishop, J. (2002). Market-based mechanisms for forest conservation and development. In S. Pagiola, J. Bishop, and N. Landell-Mills (Eds.) *Selling Forest Environmental Services*. Sterling, VA: Earthscan Publications Limited.
- Pate, J., and Loomis, J. (1997). The effect of distance on willingness to pay values: A case study of wetlands and salmon in California. *Ecological Economics* 20(3), 199-207.
- Pearce, D.W. (2001). The economic value of forest ecosystems. *Ecosystem Health* 7(4), 284-296.
- Pimentel, D. (1998). *Benefits of biological diversity in the state of Maryland*. Ithica, NY: Cornell University, College of Agricultural and Life Sciences.
- Pearce, D., Hamilton, K., and Atkinson, G. (2001). Valuing Nature. In E. van Ierland, J. van der Straaten, H. Vollebergh, and E. Elgar, (Eds.). *Economic growth and valuation of the environment: A debate*. pp. 211-24.
- Pittman, James and Batker, David. June, 2006. Special Benefit from Ecosystem Services: Economic Assessment of the King Conservation District. King Conservation District, Seattle, Washington.
- Pritchard, L. Jr., Folke, C., and Gunderson, L. (2000). Valuation of ecosystem services in institutional context. *Ecosystems*, 3(1), 36-40.
- Ribaudo, M., and Epp, D.J. (1984). The importance of sample discrimination in using the travel cost method to estimate the benefits of improved water quality. *Land Economics* 60(4), 397-403.
- Ribaudo, M.O., Piper, S., Schaible, G.D., Langner, L. L., and Colacicco, D. (1989). CRP: What

- economic benefits? *Journal of Soil and Water Conservation*. 44: 421-424.
- Sagoff, M. (1998). Aggregation and deliberation in valuing environmental public goods: A look beyond contingent valuation. *Ecological Economics* 24, 213-230.
- Salzman, J., and Ruhl, J.B. (2002). Paying to protect watershed services: Wetland banking in the United States. In S. Pagiola, J. Bishop, and N. Landell-Mills (Eds.), *Selling Forest Environmental Services*. Sterling, VA: Earthscan Publications Limited.
- Seattle Public Utilities. (2004). Tolt River Watershed. http://www.ci.seattle.wa.us/util/About_SPU/Water_System/Water_Sources_and_Treatment/Tolt_Watershed.htm (accessed 11/06/04).
- Southwick, E. E., and Southwick, L. (1992). Estimating the economic value of honey-bees (Hymenoptera, Apidae) as agricultural pollinators in the United-States. *Journal of Economic Entomology* 85(3), 621-633.
- Southwick, E. E., and Southwick, L. (1992). Estimating the economic value of honey-bees (Hymenoptera, Apidae) as agricultural pollinators in the United-States. *Journal of Economic Entomology* 85(3), 621-633.
- Thibodeau, F. R., and Ostro, B.D. (1981). An economic analysis of wetland protection. *Journal of Environmental Management* 12, 19-30.
- Turnblom, E.C., Amoroso, M.M., Ceder, K.W., Lippke, B.R., Mason, C.L., and McCarter J.B. (2002). *Estimation of Sequestered Carbon in King County Forests*. Seattle, WA: King County Department of Natural Resources. Retrieved June 1, 2004 from http://dnr.metrokc.gov/wlr/lands/forestry/pdfs/KC_Carb_Proj_Rep.pdf.
- Turner, R K., Adger, W.N., and Brouwer, R. (1998). Ecosystem services value, research needs, and policy relevance: A commentary. *Ecological Economics*, 25(1), 61-65.
- Van Beukering, P., Cesar, H., and Janssen, M. (2002). Economic valuation of the Leuser ecosystem in Sumatra. *Asean Biodiversity*. Retrieved June 1, 2004 from www.theGEF.org.
- Villa, F., Wilson, M., de Groot, R., Farber, S., Costanza, R., and R. Boumans. (2002). Designing an integrated knowledge base to support ecosystem services valuation. *Ecological Economics* 41, 445-456.
- Wilson, M.A., and Carpenter, S.R. (1999). Economic valuation of freshwater ecosystem services in the United States: 1971-1997. *Ecological Applications* 9(3), 772-783.
- Wilson, M., Costanza, R., Boumans, R., and S. Liu. 2004. Integrated assessment and valuation of ecosystem goods and services provided by coastal systems. *Biology and the Environment: Proceedings of the Royal Irish Academy*, Dublin, Ireland (accepted and in press).

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; Ribauda 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 (Ribaud 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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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.

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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 Delta¹ 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

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.

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 its 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

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 Mississippi¹⁴ 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,

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 need²⁶ 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

²⁷Coastal 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

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.

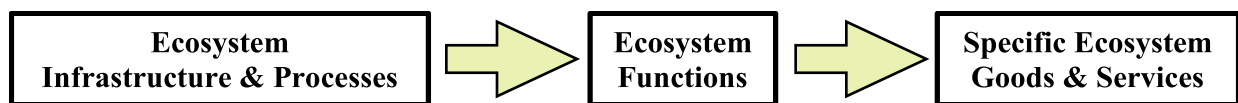
Ecosystems and Value

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		<i>Maintenance of essential ecological processes and life support systems</i>	
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		<i>Providing habitat (suitable living space) for wild plant and animal species</i>	
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		<i>Provision of natural resources</i>	
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 <i>Providing opportunities for cognitive and spiritual development</i>			
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.

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 Type⁴⁹

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

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 Desvougues 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

⁵⁰ UNEP, 2005

⁵¹ Desvougues 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.

⁵² Downing & Ozuna, 1996; Eade & Moran, 1996; Kirchoff et al., 1997; Smith, 1992, Troy and Wilson, 2006

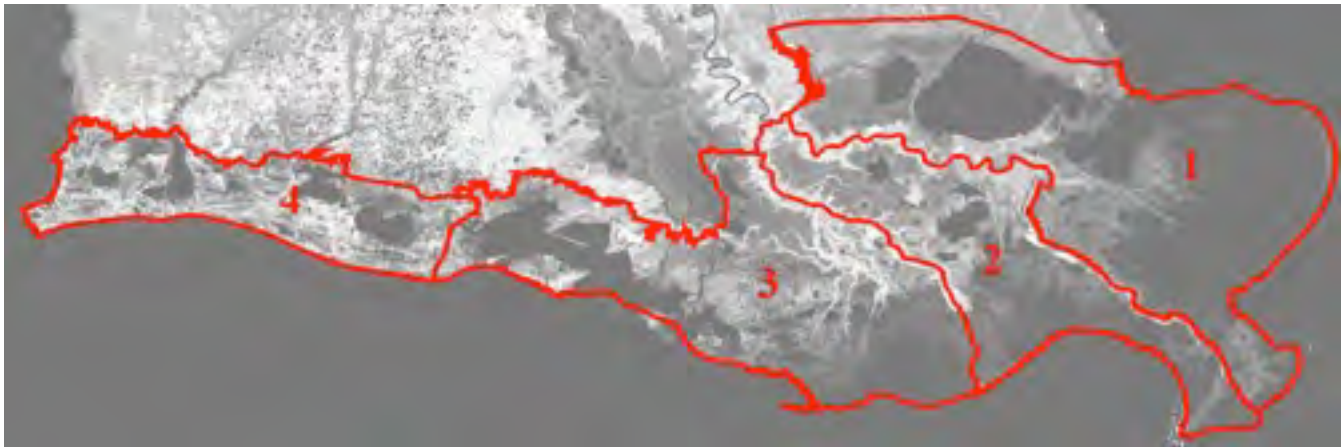
⁵³ See Spash and Vatn, 2006 for an alternative perspective

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	168,754	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 sequestration⁶¹ 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

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 CO₂ release to the atmosphere because these systems are much more energy efficient. Thus wetland assimilation reduces CO₂ 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 sources⁷¹ 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

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/m²/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/m²) and in brackish to intermediate (1300-1500 g/m²).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/m²-year. This is much greater than that of the surrounding upland forests, which are estimated at 200-1,000 g C/m²-year. Due to sulfate reduction, salt marshes do not generate significant methane. Yu et al. showed that mature Louisiana swamp forests accumulate

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 Kemp⁷⁹ have produced more recent estimates of marsh and wetland forest carbon sequestration rates which show degraded marsh sequestering 4.5 tons CO₂/acre/year, healthy marshes sequestering 11 tons CO₂/acre/yr, and wetland forests sequestering 10 tons CO₂/acre/year with forests enhanced with waste assimilation sequestering up to 25 tons CO₂/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 CO₂/acre/year for the low value of all wetland types and shrub/scrub wetlands. This study uses 11 tons CO₂/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 CO₂/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 CO₂ 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 CO₂. Being voluntary and without full participation of all CO₂ 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.

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*10⁹ per kilometer per year for permanent wetlands in terrestrial ecosystems and \$24,364.72*10⁹ 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

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 habitat⁹⁴ 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,

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 Thibodeau⁹⁷ 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 used¹⁰¹ 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	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Ecosystem Service Type																						
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	992,127	\$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 rates¹⁰³ 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 cup 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.

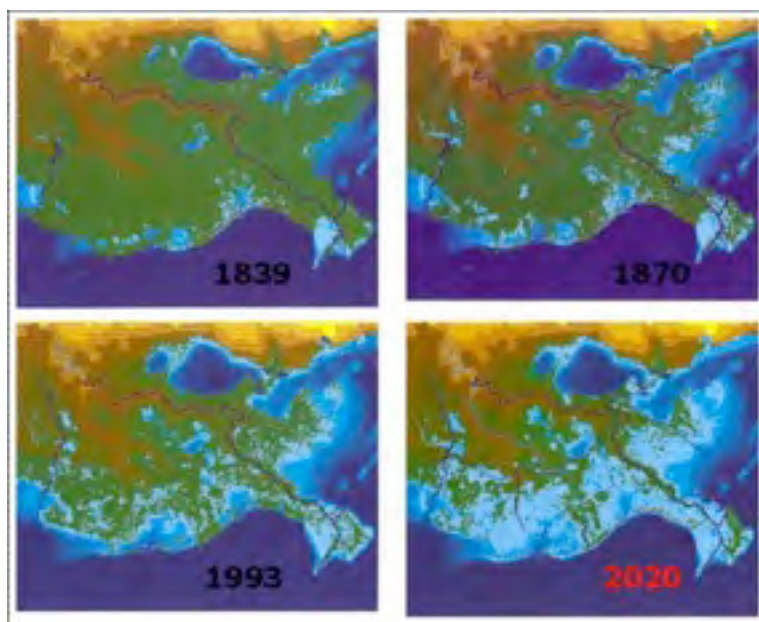
PART III: Lessons from the Delta's Physical Reality

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 year¹⁰⁷ 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 century¹¹⁴ 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.

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.

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

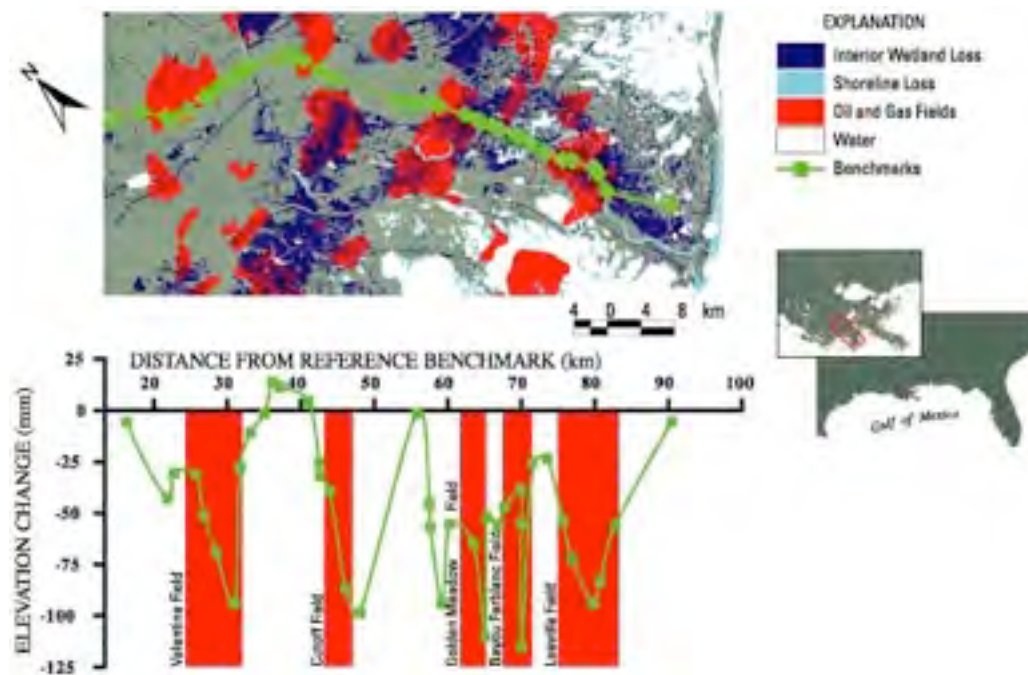
Subsidence

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.

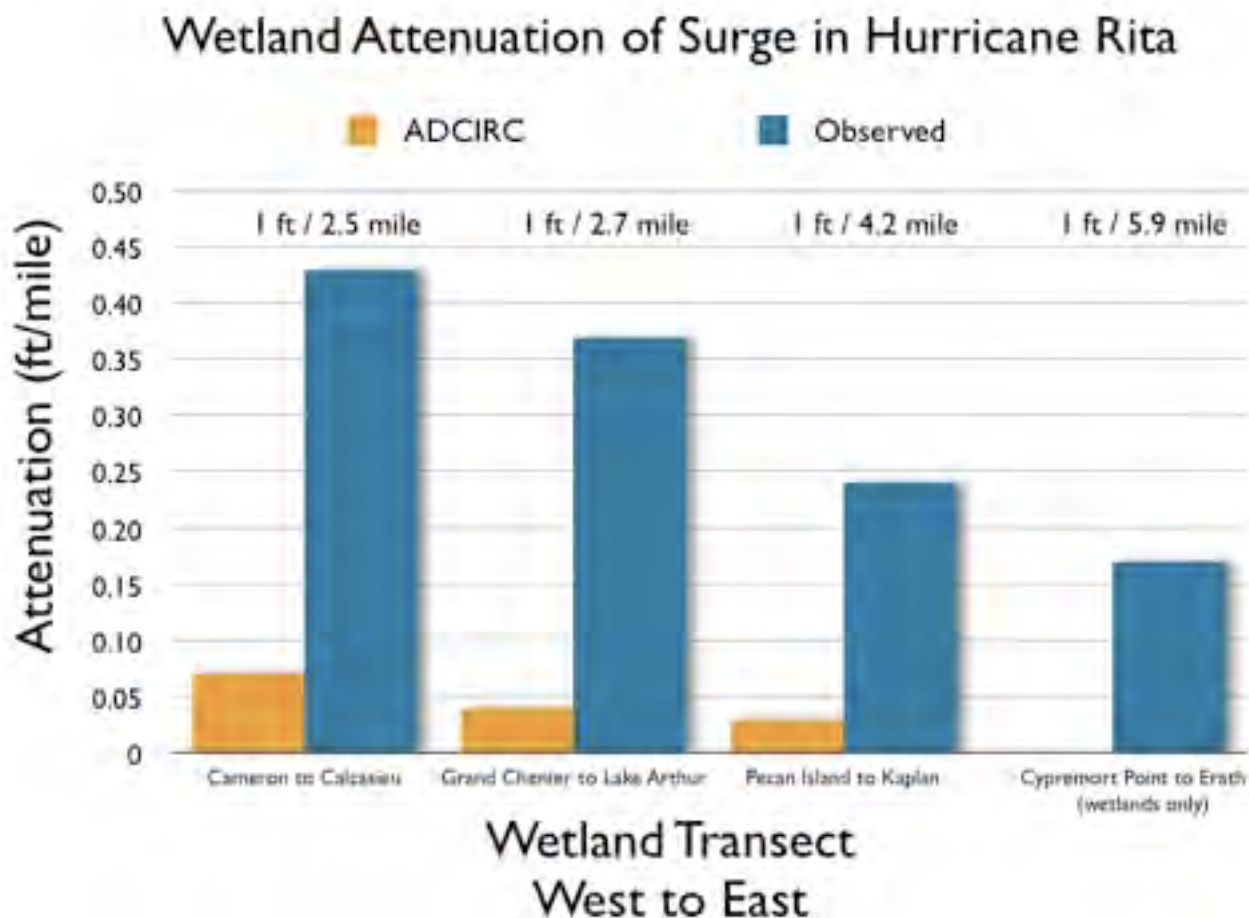
Figure 7 shows the expected attenuation (blue) based on modeling which did not include the storm surge weakening effects of wetlands and the observed attenuation (purple) for Hurricane Rita based on the physical measurement of water marks on trees and structures.

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



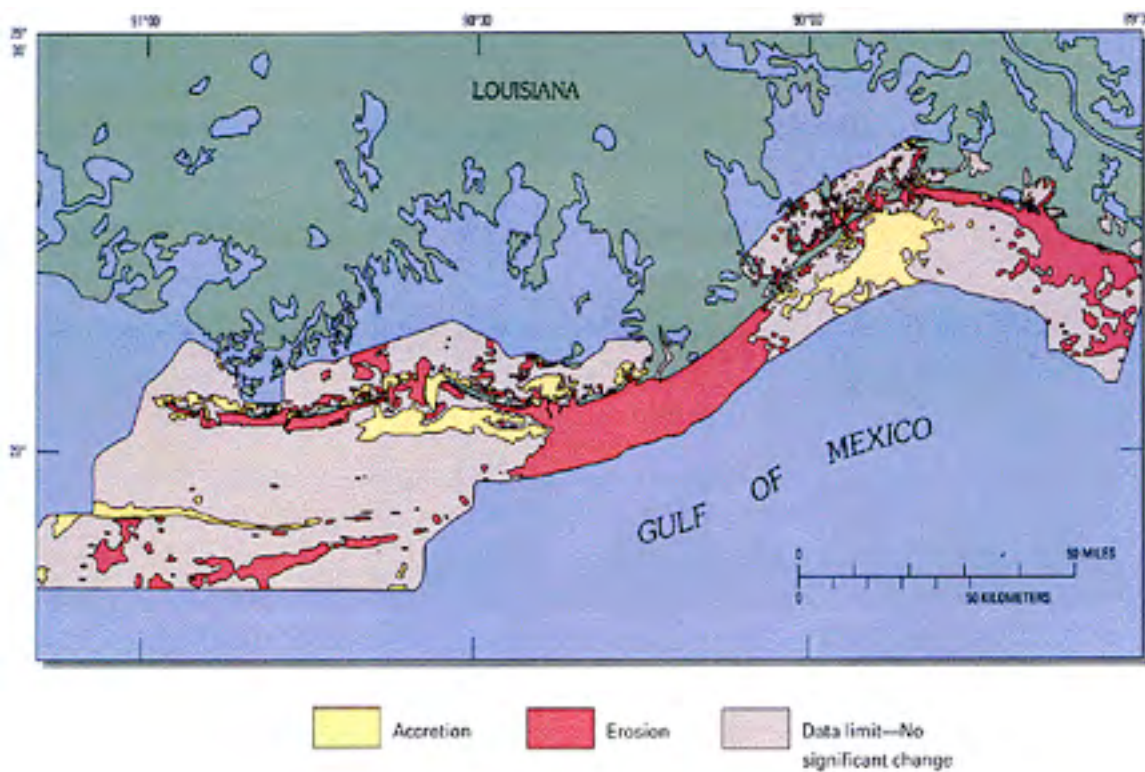
Source: Kemp and Masriqui, 2006

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

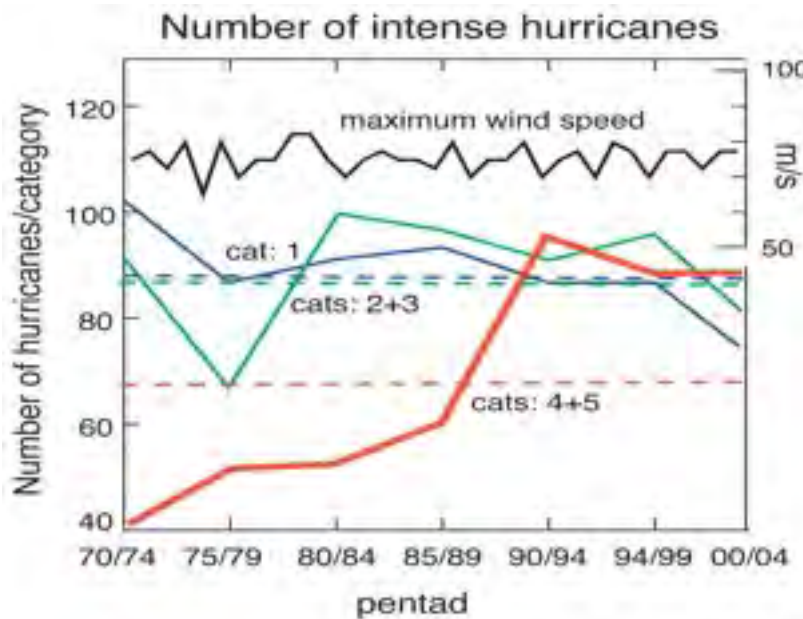
¹²⁵ Farber & Costanza, 1987

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.

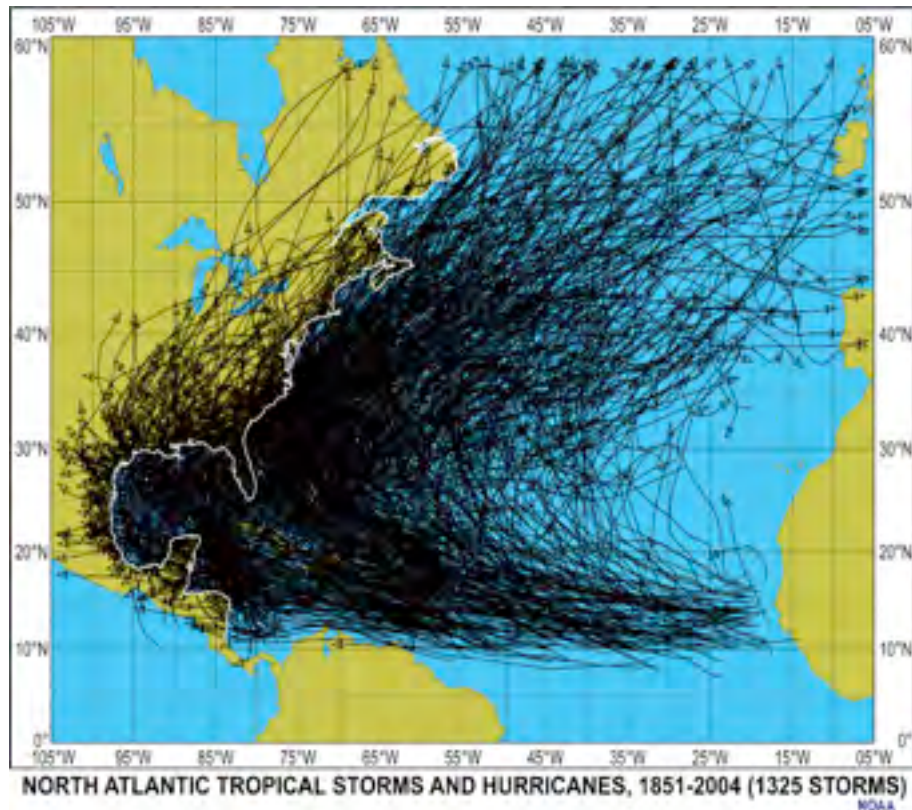
¹²⁷ Emanuel, 2005

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



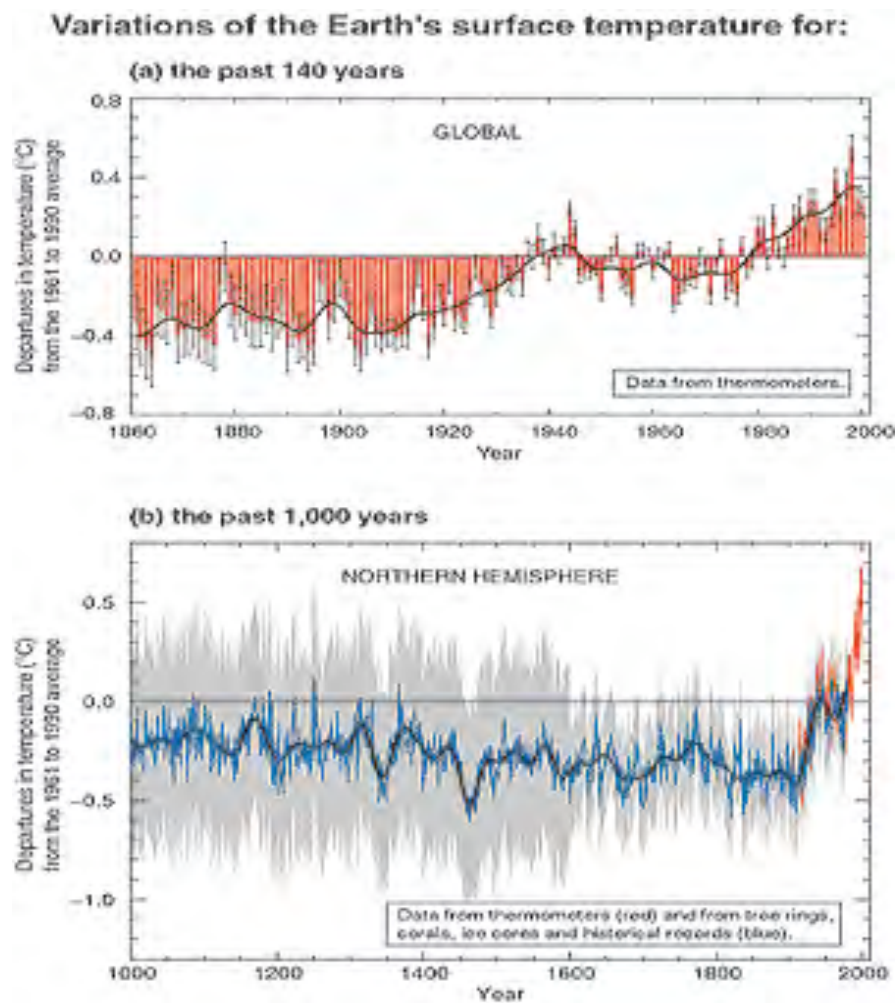
Source: NOAA

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

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

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.

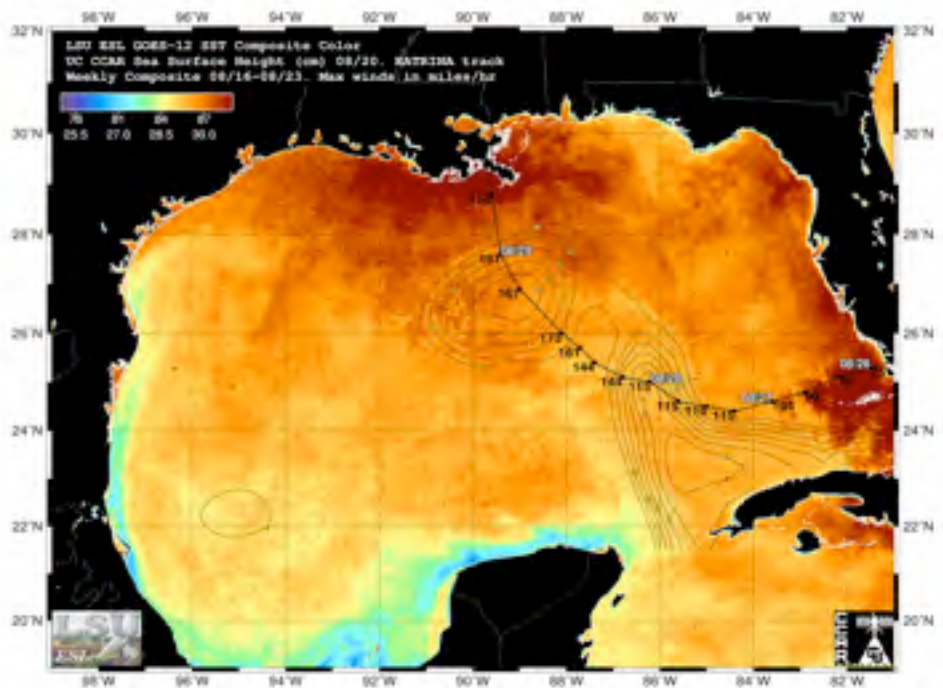
Sea Surface Temperatures

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

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.

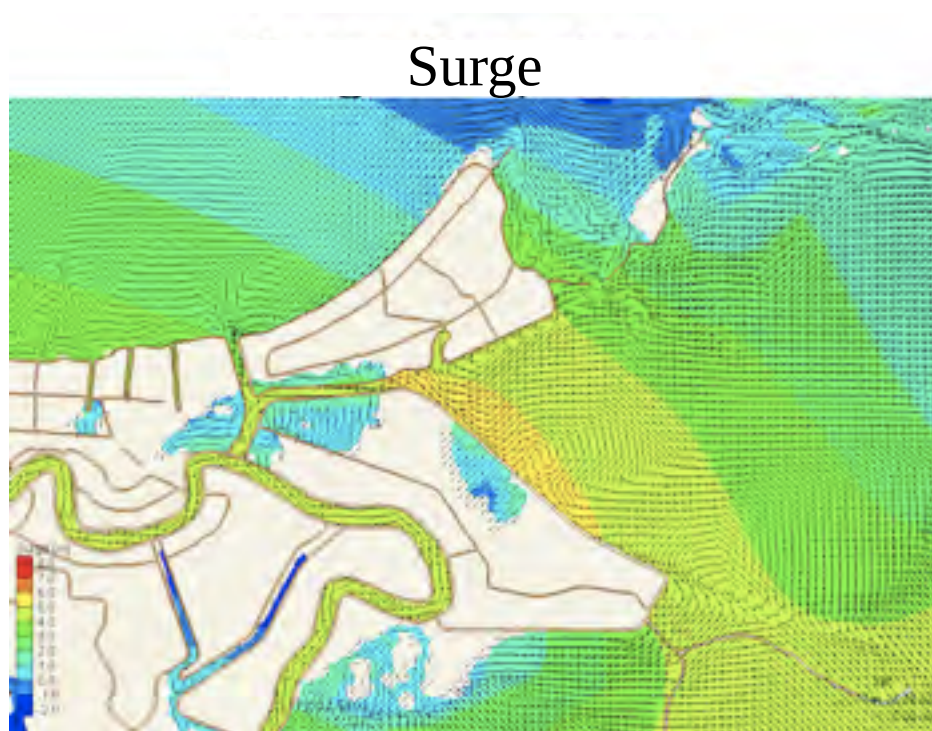
Figure 14. The “Funnel” Exposing New Orleans to Increased Storm Surge Damage



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

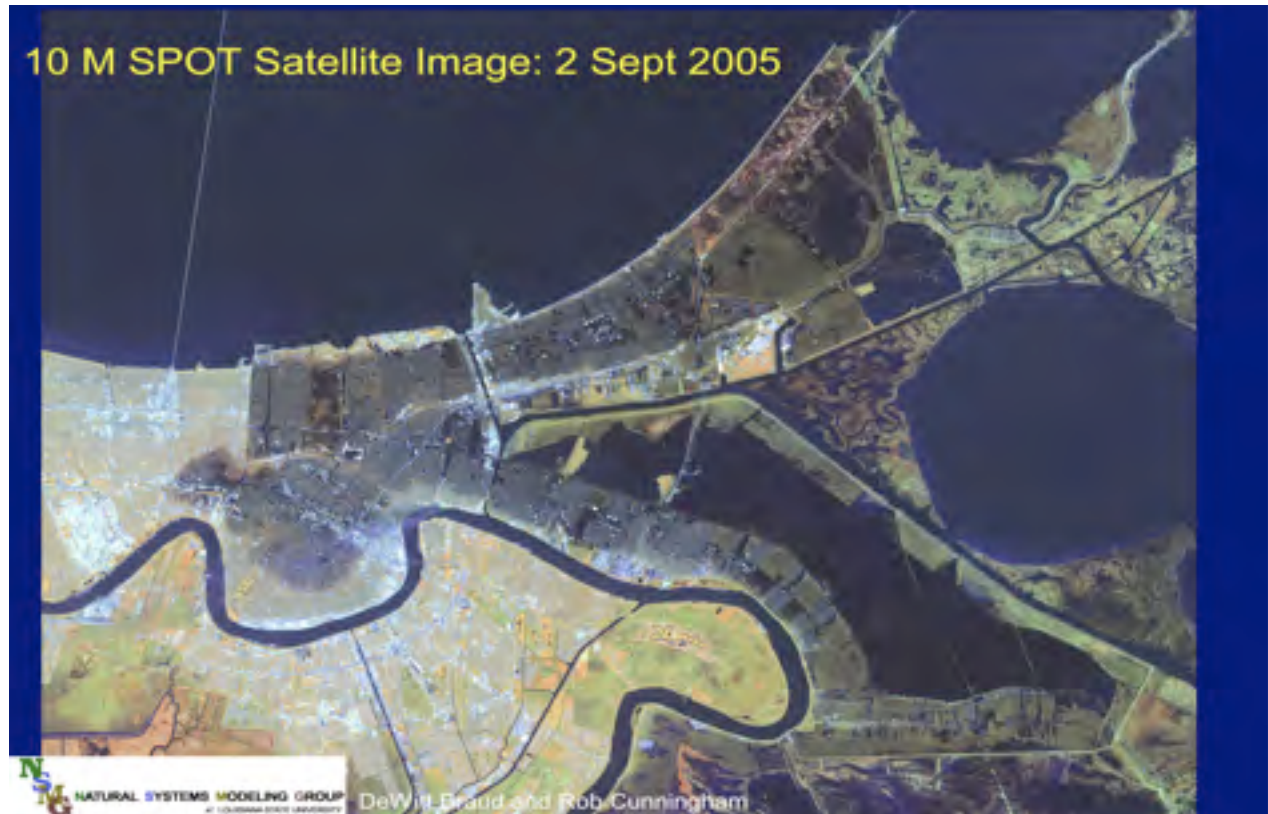
Figure 16. Storm Surge of Hurricane Katrina Amplified by Levees in the “Funnel”



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 led 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 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.

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.

References

- Army Corps of Engineers (2008). Louisiana Coastal Protection and Restoration Draft Technical Report. February 2008.
- Balmford, A., Bruner, A., Cooper, A., Costanza, R., Farber, S., Green, R., et al. (2002). Economic reasons for conserving wild nature. *Science*, 297, 950-953.
- Bart, H., Chambers, J., Gagliano, S., Bea, R., Day, J., Hester, M. et al. (2007). *Letter to Governor Blanco and Lieutenant General Strock*. (Personal Communication, 2007 March 13).
- Barras, J. A. (2007). Land area changes in coastal Louisiana after Hurricanes Katrina and Rita, in Farris, G.S., Smith, G.J., Crane, M. P., Demas, C.R., Robbins, L.L., and Lavoie, D.L., eds., *Science and the storms: the USGS response to the hurricanes of 2005*: U.S. Geological Survey Circular 1306., p. 98-113, <http://pubs.usgs.gov/circ/1306/pdf/c1306>.
- Barras, J., Beville, S., Britsch, D., Hartley, S., Hawes, S., Johnston, J., Kemp, P., Kinler, Q., Martucci, A., Porthouse, J., Reed, D., Roy, K., Sapkota, S., and Suhayda, J. (2003). Historical and projected coastal Louisiana land changes—1978–2050, Appendix B of Louisiana Coastal Area (LCA), Louisiana Ecosystem Restoration Study: U.S. Geological Survey Open-File Report 2003-334, 39 p., <http://pubs.er.usgs.gov/usgspubs/ofr/ofr0334>, accessed September 16, 2006.
- Batker, D., Swedeen, P., Costanza, R., de la Torre, I., Boumans R., Bagstad, K. (2008). *A New View of the Puget Sound Economy*. Tacoma, WA: Earth Economics.
- Baumann, R. H., & Turner, R. (1990). Direct impacts of outer continental shelf activities on wetland loss in the central Gulf of Mexico. *Environmental Geology*, 15, 189–198.
- Bergstrom, J.C., & Stahl, J. (1993). Value estimator models for wetlands-based recreational use values. *Land Economics*, 69(2), 132-137.
- Bergstrom, J.C., Stoll, J.R., Titre, J.P. & Wright, V.L. (1990). Economic Value of Wetlands-Based Recreation. *Ecological Economics*, 2(2): 129-147.
- Bergstrom, J.C., Dorfman, J and Loomis, J. (2004) Estuary Management and Recreational Fishing Benefits. *Coastal Management* December 2004, 32(16): 417-432.
- Best, C., & Wayburn, L. A. (Summer 2001). *America's Private Forests: Status and Stewardship*. Washington, D.C.: Island Press.
- Blumenthal, S. (2005). "No one can say they didn't see it coming."
Retrieved October 2007 from dir.salon.com/story/opinion/blumenthal/2005/08/31/disaster_preparation/index.html.

- Boesch, D.F. (2006). Scientific requirements for ecosystem-based management in the restoration of the Chesapeake Bay and coastal Louisiana. *Ecological Engineering*, 26, 6-26.
- Boesch, D.F., Josselyn, M., Mehta, A., Morris, J., Nuttle, W., Simenstad, C., & Swift, D. (1994). Scientific assessment of coastal wetland loss, restoration and management in Louisiana. *Journal of Coastal Research, Special Issue 20*, 1-103.
- Boumans, R., Costanza, R., Farley, J., Wilson, M., Rotmans, J., Villa, F., Porela, R., and Grasso, M. (2002). Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. *Ecological Economics*, 41, 525-560.
- Breaux, A., Farber, S. & Day, J.W. (1995). Using natural coastal wetlands systems for wastewater treatment: an economic benefit analysis. *Journal Environment Management* 44: 285-291.
- Britsch, L.D., & Dunbar, J.D. (1993). Land loss rates: Louisiana Coastal Plain. *Journal of Coastal Research*, 9, 324-338.
- Brown University. (2006). *The impact of katrina: Race and class in storm-damaged neighborhoods*. Providence, RI: Logan, J.R.
- Cardoch, L., Day, J.W., Rybczyk, J & Kemp, P. (2000). An economic analysis of using wetlands for treatment of shrimp processing wastewater -- a case study in Dulac, LA. *Ecological Economics*. 33(1): 93-101.
- Carpenter, S.R., Gunderson, L. (2001). Coping with collapse: Ecological and social dynamics in ecosystem management. *Bioscience*, 51, 451-458.
- Center for the Study of Rural America. (October 2005). *The Main Street Economist: Commentary on the rural economy*. Kansas City, KA: Drabenstott, M., & Henderson, J.
- Chesney, E. J., Baltz, D., & Thomas, R. (2000). Louisiana estuarine and coastal fisheries and habitats: Perspectives from a fish's eye view. *Ecological Applications*, 10, 350-366.
- Chicago Climate Exchange. (Mar. 1, 2006). *CCX Market Report* (Vol. iii, Num. 2). Chicago, IL: CCX.
- Chicago Climate Exchange. (Sept, 1, 2006). *CCX Market Report* (Vol. iii, Num. 8). Chicago, IL: CCX.
- Chmura, G. L., S. C. Anisfeld, D. R. Cahoon, and J. C. Lynch, 2003: Global carbon sequestration in 1 tidal, saline 2 wetland soils. *Global Biogeochemical Cycles*, 17, 1111.
- Coastal Protection and Restoration Authority. (2007a). *Louisiana's comprehensive master plan for a sustainable coast*. Baton Rouge, LA.

- Coastal Protection and Restoration Authority. (2007b). *Appendix G: Coastal Louisiana ecosystem assessment and restoration (CLEAR) report*. In *Louisiana's comprehensive master plan for a sustainable coast*. Baton Rouge, LA.
- Cole, T. (2005). The Aftermath of Hurricane Katrina. *American Chronicle*. Retrieved October 2006 from www.americanchronicle.com/articles/viewArticle.asp?articleID=2361.
- Costanza, R. (1999). The ecological, economic, and social importance of the oceans. *Ecological Economics*, 31, 199-214.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387, 253-260.
- Costanza, R., Farley, J. (2007). Ecological economics of coastal disasters: Coastal disasters special section. *Ecological Economics*, 63(2-3), 249-253.
- Costanza R., Farber, S.C. & Maxwell, J., (1989). Valuation and management of wetland ecosystems. *Ecological Economics*, 1, 335-361.
- Costanza, R., O. Perez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson, and K. Mulder (2008). The value of coastal wetlands for hurricane protection. *Ambio* 37(4): 241-248.
- Day, J.W. Jr., J. Barras, E. Clairain, J. Johnston, D. Justic, G. P. Kemp, J.-Y. Ko, R. Lane, W.J. Mitsch, G. Steyer, P. Templet, and A. Yañez-Arancibia. (2005). Implications of global climatic change and energy cost and availability for the restoration of the Mississippi Delta. *Ecological Engineering* 24:253.
- Day, J. W., L. D. Britsch, S. Hawes, G. Shaffer, D. J. Reed, and D. Calhoon (2000). Pattern and process of land loss in the Mississippi Delta: a spatial and temporal analysis of wetland habitat change. *Estuaries* 23: 425-438.
- Day, J.W., Boesch, D., Clairain, E., Kemp, G., Laska, S., Mitsch, W., et al. (2007). Restoration of the Mississippi Delta: Lessons from Hurricane Katrina and Rita. *Science*, 315, 1679.
- Day, J., Ford, M., Kemp, P, Lopez, J. (2006)j. Mister Go Must Go: A Guide for the Army Corp's Congressionally-Directed Closure of the Mississippi Gulf Outlet, Washington, DC: Environmental Defense.
- Day J.W., J. Ko, J. Rybczyk, D. Sabins, R. Bean, G. Berthelot, C. Brantley, L. Cardoch, W. Conner, J. N. Day, A. . Englande, S. Feagley, E. Hyfield, R. Lane, J. Lindsey, J. Mitsch, E. Reyes, and R. Twilley (2004). The use of wetlands in the Mississippi delta for wastewater assimilation: a review. *Ocean and Coastal Management* 47:671-691.

- Day, J., Martin J, Cardoch, L, and Templet, P. (1997). System functioning as a basis for sustainable management of deltaic ecosystems. *Coastal Management*. 25:115-154.
- Day, J., Shaffer, G, Britsch, L, Reed, D, Hawes, S. and Cahoon, D.. (2000). Pattern and process of land loss in the Mississippi delta: A spatial and temporal analysis of wetland habitat change. *Estuaries*. 23: 425-438.
- Day, J.W., Yañez, A., Mitsch, W., Lara-Dominguez, A., Day, J., Ko, J., Lane, R., Lindsey, J., & Zarate, D. (2003). Using ecotechnology to address water quality and wetland habitat loss problems in the Mississippi Basin. *Biotechnology Advances*, 22, 135-159.
- Daily, G.C. (1997). *Nature's services: Societal dependence on natural ecosystems*. Washington, DC: Island Press.
- Daly, H. & Farley, J. (2004). *Ecological economics: Principles and applications*. Washington, DC: Island Press.
- De Groot, R., Wilson, M., & Boumans, R. (2002). A typology for the classification, description, and valuation of ecosystem functions, goods, and services. *Ecological Economics*, 41, 393-408.
- Desvougues, W., Johnson, F., & Banzhaf, H. (1998). *Environmental policy analysis with limited information: Principles and applications of the transfer method*. Northampton, MA: Edward Elgar Publishing.
- Dismukes, D., Mesyanzhinov, D., Burke, J., Baumann, R., (2004). *Marginal Oil and Gas Production in Louisiana: An Empirical Examination of State Activities and Policy Mechanisms for Stimulating Additional Production*. Baton Rouge, LA: Office of Mineral Resources, Louisiana Department of Natural Resources.
- Earth Economics. (2006). *Special benefits from ecosystem services: Economic assessment of the King Conservation District*. Tacoma, WA: Batker, D. and Pittman, J.
- Earth Scan Laboratory. (2008) Louisiana State University. <http://www.esl.lsu.edu/home/>.
- Ecosystem Marketplace. *Markets watch, carbon markets*, http://ecosystemmarketplace.com/pages/marketwatch.segment_landing.carbon.php?component_class_name_csv=carbon_market,carbon_aggregate_market (September, 2007).
- Eilperin, J. (2005). *World temperatures keep rising with a hot 2005*. Retrieved October 2007 from http://www.stopglobalwarming.org/sgw_read.asp?id=12405111172005.
- Emanuel, K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, 436, 686-688.

- Environmental Protection Agency. (2005). *Response to 2005 Hurricanes: Murphy Oil Spill*. Washington, D.C. Retrieved October 2006 from <http://www.epa.gov/katrina/testresults/murphy/index.html>.
- Environmental Protection Agency. (2004). *Watershed academy training*. Washington, DC: U.S. Government Printing Office. Retrieved June 2004 from www.epa.gov/watertrain/.
- Farber, S. (1996). Welfare loss of wetlands disintegration: A Louisiana study. *Contemporary Economic Study*, 14(1), 92-106.
- Farber, S., & Costanza, R. (1987). The economic value of wetlands systems. *Journal of Environmental Management*, 24(1), 41-51.
- Farley, J., Batker, D., Pittman, J. (2006). Opening the policy window for ecological economics: Katrina as a focusing event. *Ecological Economics*, 63, 344-354.
- Federal Trade Commission. (2006, June 30). *Gasoline column: Focus on gasoline retailing*. Washington, D.C. Retrieved October 2006 from <http://www.ftc.gov/ftc/oilgas/archive/060630.htm>.
- Fletcher, J. & Efrati, A. (2005, September 22). Katrina causes prices for homes to diverge along the gulf coast. *The Wall Street Journal Online*. Retrieved October 2006 from <http://www.realestatejournal.com/buysell/regionalnews/20050922-fletcher.html?refresh=on>.
- Fritz, H.M., Blount, C., Sokoloski, R., Singleton, J., Fuggle, A., McAdoo, B. (2007). Hurricane Katrina storm surge distribution and field observations on the Mississippi Barrier Islands. *Estuarine Coastal and Shelf Science*, 74, 1-2.
- Gaddis E.B., Brian M., Morse, S., & Lewis, D. (2005). Full cost accounting of coastal disasters in the United States: Implications for planning and preparedness. *Ecological Economics*, 63, 307-318.
- Gagliano, S. M., Meyer-Arendt, K. J., & Wicker, K. M. (1981). Land loss in the Mississippi River Deltaic Plain: Transactions. *Gulf Coast Association of Geological Societies*, 31, 295-300.
- Gitz, V., Hourcade, J., & Ciais, P. (2006). The timing of biological carbon sequestration and carbon abatement in the energy sector under optimal strategies against climate risks. *Energy Journal*, 27(3), 113-133.
- Gramling, R., & Hagelman, R. (2005). A working coast: People in the Louisiana Wetlands. *Journal of Coastal Research, Special Issue 44*, 112-133.

- Gund Institute for Ecological Economics. (2006a). *Assessing the non-market values of ecosystem services provided by coastal and marine systems: Revealing a monetary baseline for coastal and marine markets*. Burlington, VT: Wilson, M.A., & Liu, S.
- Gund Institute for Ecological Economics. (2006b). *The value of New Jersey's ecosystem services and natural capital*. Burlington, VT: Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., & D'Agostino, J.
- Gunderson, L.H., & Holling, C. (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.
- Hall, C., and J. Day, eds. (1977). *Ecosystem modeling in theory and practice*. Wiley Interscience, New York.
- Hatton R.S., DeLaune R.D., & Patrick W.H., Jr. (1983). Sedimentation, accretion, and subsidence in marshes of Barataria, Louisiana. *Limnology and Oceanograph*, 28, 494-502.
- Hesse, I., Doyle, T. & Day, J.W.. (1998). Long-term growth enhancement of baldcypress (*Taxodium distichum*) from nunicipal wastewater application. *Environmental Management*. 22:119-127.
- Howarth, R. and S. Farber. (2002). Accounting for the value of ecosystem services. *Ecological Economics*, vol. 41, issue 3, pages 421-429.
- Hsu, S. (2006, January 13). 2 Million displaced by storms. *Washington Post*, pp. A03.
- Intergovernmental Panel on Climate Change Working Group I. (2001). *Climate change 2001: Working group I: The scientific basis: Summary for policymakers*. Boulder, CO: Author unknown. Retrieved October 2005 from http://www.grida.no/climate/ipcc_tar/wg1/005.htm.
- Kazmierczak, R.F. (2001). Economic linkages between coastal wetlands and habitat/species protection: A review of value estimates reported in the published literature. Natural Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Centre.
- Kesel, R.H. (1988). The decline in the suspended load of the lower Mississippi River and its influence on adjacent wetlands. *Environmental Geology*, 11, 271-281.
- Kesel, R.H. (1989). The role of the Mississippi River in wetland loss in Southern Louisiana, USA. *Environmental Geology*, 13, 183-193.
- Krupa, M. (2006, March 5). Presumed missing. Message posted to <http://whodatzone.com/forum/index.php?showtopic=9998>.

- Lake Pontchartrain Basin Foundation and Coalition to Restore Coastal Louisiana. (2008). Comprehensive Recommendations Supporting the Use of the Multiple Lines of Defense Strategy to Sustain Coastal Louisiana 2008 Report (Version I). Lake Pontchartrain Basin Foundation, Metairie, LA.
- Landsea, C. (2005). *Subject: G4) Why do tropical cyclones occur primarily in the summer and autumn?* Retrieved October 2007 from www.aoml.noaa.gov/hrd/tcfaq/G4.html.
- Laska, S., Woodell, G., Hagelman, R., Gramling, R., & Teets-Farris, M. (2005). At risk: the human, community and infrastructure resources of coastal Louisiana. *Journal of Coastal Research, Special Issue 44*, 90-111.
- Leschine, T, Wellman, K., and Green, T. (1997). The economic value of wetlands: wetland's role in flood protection in Western Washington. Washington State Department of Ecology publication 97-100, Olympia, Washington.
- Limburg, K., O'Neill, R., Costanza, R., & Farber, S. (2002). Complex systems and valuation. *Ecological Economics*, 41, 409-420.
- Lindstedt, D.M. (2005). Renewable resources at stake: Barataria-Terrebonne estuarine system in southeast Louisiana. *Journal of Coastal Research* 44: 162-175.
- Llanos, M. (2005). 44 oil spills found in Southeast Louisiana. MSNBC website, Sept. 19, 2005. <http://www.msnbc.msn.com/id/9365607/>.
- Louisiana Department of Health and Hospitals. (2006). *Report of Missing and Deceased*. Baton Rouge, LA.
- Louisiana Department of Transportation. (2007). *The Failure of the New Orleans Levee System During Hurricane Katrina*. Baton Rouge, LA.
- Louisiana State University Department of Agricultural Economics and Agribusiness (2001). *Economic linkages between coastal wetlands and water quality: a review of the value estimates reported in the published literature*. Baton Rouge, LA: Kazmierczak, R. Jr.
- Mahan, B., Polasky, S., & Adams, R. (2000). Valuing urban wetlands: a property price approach. *Land Economics*, 76(1), 100-113.
- Martinez, M. & Intralawan, A. (2006). The ecological, economic and social importance of the coasts. *Ecological Economics*, 10, 10-16.
- Martínez, M.L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton P. & Landgrave, R. The coasts of our world: Ecological, economic and social importance. *Ecological Economics*, 63, 254-272.

- McCormack, J. (2006, April). Lessons learned from katrina. *Insurance Networking News*.
- Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-Being: Wetlands and Water (Synthesis)*. Washington, D.C.: World Resources Institute.
- Mitsch, W., Day, J., Gilliam, J., Groffman, P., Hey, D., Randall, G., & Wang, N. (2001). Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River basin : Strategies to counter a persistent problem. *BioScience* 51, 373-388.
- Morton, R.A., Buster, N.A., & Krohn, M.D. (2002). Subsurface controls on the historical subsidence rates and associated wetland loss in south central Louisiana. *Gulf Coast Association of Geological Societies Transactions*, 52, 767-778.
- National Biological Survey. (1994). *Land loss in coastal Louisiana 1956-90*. (Open File Report 94-01). Washington, D.C: Barras, J.A., Bourgeois, P.E. & Handley, L.R.
- National Oceanic and Atmospheric Administration. (2005). *Climate of 2005 Summary of Hurricane Katrina*. Retrieved December 2005 from <http://www.ncdc.noaa.gov/oa/climate/research/2005/katrina.html#rain>.
- New Jersey Department of Environmental Protection. (2007). *Valuing New Jersey's natural capital: An assessment of the economic value of the state's natural resources*. Retrieved June 2004 from <http://njedl.rutgers.edu/ftp/PDFs/4629.pdf>.
- Pearce, D.W. & Pearce, C.G. (2001). *The value of forest ecosystems*. Report to the Secretariat of the United Nations Convention on Biological Diversity. Montreal, Canada.
- Pilkey, O.H. (2003, May 3). A celebration of the world's Barrier Islands. *Columbia University Press*. Retrieved November 11, 2007 from www.earthscience.org/r3/ES15355/Pilkey-ch05.pdf.
- Rahmstorf, S., Ammann, C., Archer, D., Steig, E., Schmitt, G., Mann, M., et al. (2007, March 27). The IPCC sea level numbers. Messages posted to <http://www.realclimate.org/index.php/archives/2007/03/the-ipcc-sea-level-numbers/>.
- Stone, G.W., Zhang, X., & Sheremet, A. (2005). The role of Barrier Islands, Muddy Shelf, and reefs in mitigating the wave field along coastal Louisiana. *Journal of Coastal Research*, 44, 40-55.
- Swenson, E.M., & Turner, R.E. (1987). Spoil banks: Effects on a coastal marsh water-level regime. *Estuarine Coastal and Shelf Science*, 24, 599-609.
- Thibodeau, F. & Ostro, B. (1981). An economic analysis of wetland protection. *Journal of Environmental Management*, 12, 19-30.

- Tibbets, J. (2006). Louisiana's wetlands: A lesson in nature appreciation. *Environmental Health Perspective*, 114, A40-A43.
- Trulio, L. (May 20, 2007). *Notes on Carbon Sequestration and Tidal Salt Marsh Restoration*. Retrieved September 2007 from http://www.sfbayjv.org/tools/climate/CarbonWtlandsSummary_07_Trulio.pdf.
- Tol, R.S.J. (2005). The Marginal damage costs of carbon dioxide emissions: An assessment of the uncertainties. *Energy Policy*, 33 (16), 2064-2074.
- Twilley, R.R., and Barras, J. (2004), Formulation of the LCA ecosystem model, in Hydrodynamic and ecological modeling, Louisiana Coastal Area (LCA)—Louisiana ecosystem restoration plan, Vol. 4, Appendix C, Chapter 2: <http://www.lca.gov/appc.aspx>, accessed August 9, 2006.
- United Nations Environment Programme. (2006). *Observed climate trends*. New York, NY: Author(s) unknown. Retrieved October 2007 from <http://www.grida.no/climate/vital/19.htm>.
- United Nations Environment Programme. (2005). *UNEP annual report, 1*, ch. 19. New York, NY: Author(s) unknown.
- U.S. Army Corps of Engineers. (2007). *The facts*. Retrieved December 2007 from <http://www.usace.army.mil/thefacts.htm>.
- U.S. Army Corps of Engineers. (2005). *Estimate of the Cost of the Coast 2050 Blueprint*. Washington, D.C: U.S. government printing office.
- U.S. Census Bureau. (2000). *Educational attainment in the United States (Update): Population characteristics*. Retrieved June 2004 from www.census.gov/population/socdemo/education/p20-536/p20-536.pdf.
- U.S. Geological Survey. (2006). *Land area change in coastal Louisiana after the 2005 hurricanes—A series of three maps*. (Open-File Report 06-1274). Washington, D.C.: Barras, J.A.
- U.S. Geological Survey (2005). Water Q &A: Water use at home. In *Water Science for Schools*. Washington, D.C: Perlman, Howard. Retrieved October 2007 from <http://ga.water.usgs.gov/edu/qahome.html>.
- U.S. Geological Survey. (2003). *Historical and projected coastal Louisiana land changes: 1978-2050*. (Open File Report 03-334). Washington, D.C.: Barras, J.A., Beville, S., Britsch, D., Hartley, S., Hawes, S., Johnston, J., Kemp, P., Kinler, Q., Martucci, A., Porthouse, J., Reed, D., Roy, K., Sapkota, S., & Suhayda, J.
- U.S. Federal Reserve Bank. (2009). Open Market Committee Press Release, January 28, 2009. Washington, D.C.

- U.S. Geological Survey. (2002). *Environmental atlas of Lake Pontchartrain*. Washington, D.C. Retrieved October 2002 from <http://pubs.usgs.gov/of/2002/of02-206/env-status/table.html#table5>.
- U.S. Government Accountability Office. (2006). *Hurricane Katrina: Better plans and exercises needed to guide the military's response to catastrophic natural disasters*. (GAO Report: GAO-06-643). Washington, D.C.
- Webster, P.J. & Curry, J.A. (2005). Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science*, 309, 1844-1846.
- Wilson, M., Troy, A., & Costanza, R. (2004). The geography of ecosystem services: Maximizing the value of landscapes in land use conservation. In M. Dietrich and J. van der Straaten (eds.), *Cultural Landscapes* (69-94). Dordrecht, Netherlands: Kluwer Academic Publishers.
- Working Group for Post-Hurricane Planning for the Louisiana Coast. (2006). *A new framework for planning the future of coastal Louisiana after the hurricanes of 2005*. Cambridge, MD: Boesch, B.F., Shabman, L., Antle, G., Day, J., Dean, R., Galloway, G., et al.
- Yu K. & DeLaune R.D. (2006). A modified soil diffusion chamber for gas profile analysis. *Soil Science Society of America*, 70:1237-1241. Retrieved October 2007 from <http://soil.sciijournals.org/cgi/content/full/70/4/1237>.

APPENDICES

APPENDIX A: List of Value-Transfer Studies Used for Data Sources

- Alvarez-Farizo, B., N. Hanley, R.E. Wright, and D. MacMillan. 1999. Estimating the benefits of agri-environmental policy: econometric issues in open-ended contingent valuation studies. *Journal Of Environmental Planning And Management* 42: 23-43.
- Amigues, J. P., C. Boulatoff, B. Desaignes, C. Gauthier, and J. E. Keith. 2002. The benefits and costs of riparian analysis habitat preservation: a willingness to accept/willingness to pay contingent valuation approach. *Ecological Economics* 43: 17-31.
- American Water Works Association (AWWA). 2007. Desalination. http://www.awwa.org/Advocacy/pressroom/Desalination_083105.cfm, last accessed May 6, 2007.
- Bell, F. W. 1997. The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States. *Ecological Economics* 21: 243-254.
- Bergstrom, J., B.L. Dillman, and J. R. Stoll. 1985. Public environmental amenity benefits of private land: the case of prime agricultural land. *South Journal of Agricultural Economics* 7: 139-149.
- Bergstrom, J. C., J. R. Stoll, J. P. Titre, and V. L. Wright. 1990. Economic value of wetlands-based recreation. *Ecological Economics* 2: 129-147.
- Bishop, Kevin. 1992. Assessing the Benefits of Community Forests: An Evaluation of the Recreational of Use Benefits of Two Urban Fringe Woodlands. *Journal of Environmental Planning and Management* 35: 63-76.
- Bocksteal, N.E., K.E. McConnell, and I.E. Strand. 1989. Measuring the Benefits of Improvements in Water Quality: The Chesapeake Bay. *Marine Resource Economics* 6: 1-18.
- Bowker, J.M., D. English, and J. Donovan. 1996. Toward a value for guided rafting on southern rivers. *Journal of Agricultural and Resource Economics* 28: 423-432.
- Breaux, A., S. Farber, and J. Day. 1995. Using Natural Coastal Wetlands Systems for Waste-Water Treatment - an Economic Benefit Analysis. *Journal of Environmental Management* 44: 285-291.
- Chmura G.L., S.C. Anisfeld, D.R. Cahoon, and J.C. Lynch. 2003. Global carbon sequestration in tidal, saline wetland soils. *Global Biogeochemical Cycles* 17(4): Art. No. 1111 Dec 10 2003.
- Costanza, R., O. Perez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson, and K. Mulder. 2008. The value of coastal wetlands for hurricane protection. *Ambio* 37(4): 241-248.

- Doss, C. R. and S. J. Taff. 1996. The influence of wetland type and wetland proximity on residential property values. *Journal of Agricultural and Resource Economics* 21: 120-129.
- Edwards, S. F. and F.J. Gable. 1991. Estimating the value of beach recreation from property values: an exploration with comparisons to nourishment costs. *Ocean & Shoreline Management* 15: 37-55.
- Farber, S. 1987. The value of coastal wetlands for protection of property against hurricane wind damage. *Journal of Environmental Economics and Management* 14: 143-151.
- Farber, S. 1996. Welfare loss of wetlands disintegration: A Louisiana study. *Contemporary Economic Policy* 14: 92-106.
- Farber, S. and R. Costanza. 1987. The Economic Value of Wetlands Systems. *Journal of Environmental Management* 24: 41-51.
- Greenley, D., R. G. Walsh, and R.A. Young. 1981. Option value: empirical evidence from study of recreation and water quality. *The Quarterly Journal of Economics*: 657-673.
- Haener, M.K. and Adamowitz, W.L. 2000. Regional forest resource accounting: A northern Alberta case study. *Canadian Journal of Forest Research* 30: 264-273.
- Johnston, R. J., T. A. Grigalunas, J. J. Opaluch, M. Mazzotta, and J. Diamantides. 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. *Coastal Management* 30: 47-65.
- Kazmierczak, R.F., Jr. 2001. Economic linkages between coastal wetlands and water quality: A review of value estimates reported in the published literature. Natural Resource and Environment Committee, LSU Agricultural Economics and Agribusiness. Staff Paper 2001 02.
- Kline, J. D. and S. K. Swallow. 1998. The demand for local access to coastal recreation in southern New England. *Coastal Management* 26: 177-190.
- Lant, C. L. and G. Tobin. 1989. The economic value of riparian corridors in cornbelt floodplains: a research framework. *Professional Geographer* 41: 337-349.
- Leschine, T, Wellman, K., and Green, T. (1997). The economic value of wetlands: wetland's role in flood protection in Western Washington. Washington State Department of Ecology publication 97-100, Olympia, Washington.
- Lindstedt, D.M. 2005. Renewable resources at stake: Barataria-Terrebonne estuarine system in southeast Louisiana. *Journal of Coastal Research* 44: 162-175.
- Lynne, G.D., P. Conroy, and F.J. Prochaska. 1981. Economic Valuation of Marsh Areas for Marine Production Processes. *Journal of Environmental Economics and Management* 8: 175-186.

- Mathews, L. G., F. R. Homans, and K. W. Easter. 2002. Estimating the benefits of phosphorus pollution reductions: An application in the Minnesota River. *Journal of the American Water Resources Association* 38: 1217-1223.
- McPherson, E. G. 1992. Accounting for Benefits and Costs of Urban Greenspace. *Landscape and Urban Planning* 22: 41-51.
- McPherson, E. G., K. I. Scott, and J. R. Simpson. 1998. Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models. *Atmospheric Environment* 32: 75-84.
- Parsons, G. R. and M. Powell. 2001. Measuring the Cost of Beach Retreat. *Coastal Management* 29: 91-103.
- Pate, J. and J. Loomis. 1997. The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. *Ecological Economics* 20: 199-207.
- Patrick, R., J. Fletcher, S. Lovejoy, W. Vanbeek, G. Holloway, and J. Binkley. 1991. Estimating Regional Benefits of Reducing Targeted Pollutants - an Application to Agricultural Effects on Water-Quality and the Value of Recreational Fishing. *Journal of Environmental Management* 33: 301-310.
- Pearce, D.W. 2001. The economic value of forest ecosystems. *Ecosystem Health* 7 (4): 284-296.
- Pimentel, D., C. Wilson, C. McCullum, R. Huang, P. Dwen, J. Flack, Q. Tran, T. Saltman, and B. Cliff. 1997. Economic and environmental benefits of biodiversity. *Bioscience* 47: 747-757.
- Piper, S. 1997. Regional impacts and benefits of water-based activities: an application in the Black Hills region of South Dakota and Wyoming. *Impact Assessment* 15: 335-359.
- Pompe, J. J. and J. R. Rinehart. 1995. Beach Quality and the Enhancement of Recreational Property-Values. *Journal of Leisure Research* 27: 143-154.
- Rein, F. A. 1999. An economic analysis of vegetative buffer strip implementation - Case study: Elkhorn Slough, Monterey Bay, California. *Coastal Management* 27: 377-390.
- Reyes, J. and W. Mates. 2004. The economic value of New Jersey State Parks and Forests. New Jersey Department of Environmental Protection.
- Ribaudo, M. and D.J. Epp. 1984. The importance of sample discrimination in using the travel cost method to estimate the benefits of improved water quality. *Land Economics* 60: 397-403.
- Rich, P. R. and L. J. Moffitt. 1982. Benefits of Pollution-Control on Massachusetts Housatonic River - a Hedonic Pricing Approach. *Water Resources Bulletin* 18: 1033-1037.
- Robinson, W.S, R. Nowogrodzki, and R.A. Morse. 1989. The value of honey bees as pollinators of U.S. crops. *American Bee Journal*: 177-487.

- Southwick, E. E. and L. Southwick. 1992. Estimating the Economic Value of Honey-Bees (Hymenoptera, Apidae) as Agricultural Pollinators in the United-States. *Journal of Economic Entomology* 85: 621-633.
- Taylor, L. O. and V. K. Smith. 2000. Environmental amenities as a source of market power. *Land Economics* 76: 550-568.
- Thibodeau, F. R. and B.D. Ostro. 1981. An economic analysis of wetland protection. *Journal of Environmental Management* 12: 19-30.
- Tol, R.S.J. 2005. The marginal costs of carbon dioxide emissions: An assessment of the uncertainties. *Energy Policy* 33: 2064-2074.
- Tyrvaainen, L. 2001. Economic valuation of urban forest benefits in Finland. *Journal of Environmental Management* 62: 75-92.
- Vankooten, G. C. and A. Schmitz. 1992. Preserving Waterfowl Habitat on the Canadian Prairies - Economic Incentives Versus Moral Suasion. *American Journal of Agricultural Economics* 74: 79-89.
- Ward, F. A., B. A. Roach, and J. E. Henderson. 1996. The economic value of water in recreation: Evidence from the California drought. *Water Resources Research* 32: 1075-1081.
- Whitehead, J. C., T. L. Hoban, and W. B. Clifford. 1997. Economic analysis of an estuarine quality improvement program: The Albemarle-Pamlico system. *Coastal Management* 25: 43-57.
- Willis, K. G. 1991. The Recreational Value of the Forestry Commission Estate in Great-Britain - a Clawson-Knetsch Travel Cost-Analysis. *Scottish Journal of Political Economy* 38: 58-75.

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	Thibodeau 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, Ribaud 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	Tyrvaainen 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	Thibodeau 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	Thibodeau 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 for 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 be 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 ecosystems 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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