ACCOUNTING FOR ENVIRONMENTAL CHANGE

A MODERNIZED APPROACH TO BENEFIT-COST ANALYSIS ON THE UPPER MISSISSIPPI RIVER

EARTH ECONOMICS

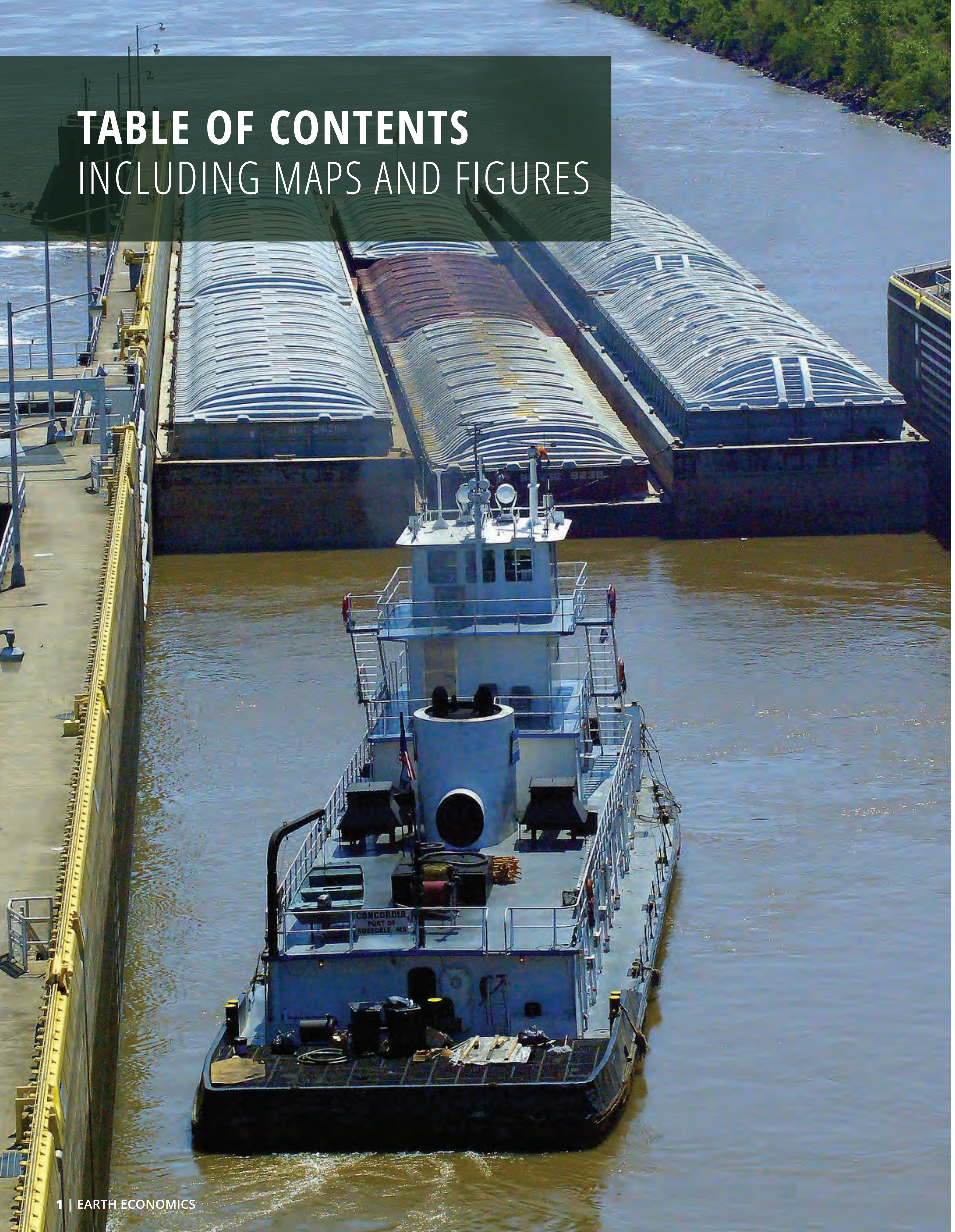


TABLE OF CONTENTS
INCLUDING MAPS AND FIGURES

AUTHORS

Tania Briceno, Ken Cousins, Trygve Madsen, Jared Soares

Suggested Citation: *Briceno, T., Cousins, K., Madsen, T., Soares, J., 2019. Accounting for Environmental Change: A Modernized Approach to Benefit-Cost Analysis on the Upper Mississippi River. Earth Economics, Tacoma, WA.*

ACKNOWLEDGMENTS

Map design by Corrine Armistead and Nina Kerr
Report design by Cheri Jensen
Editing by Jessie Martin and Michael Burnham

Funding provided by the McKnight Foundation.

We would also like to thank Earth Economics' Board of Directors for their continued guidance and support: Alex Bernhardt, David Cosman, Elizabeth Hendrix, Greg Forge, Ingrid Rasch, Molly Seaverns, Nan McKay, and Sherry Richardson.

The authors are responsible for the content of this report.

Earth Economics is a leader in ecological economics.
We quantify and value the benefits nature provides.

eartheconomics.org | info@eartheconomics.org

EARTH ECONOMICS

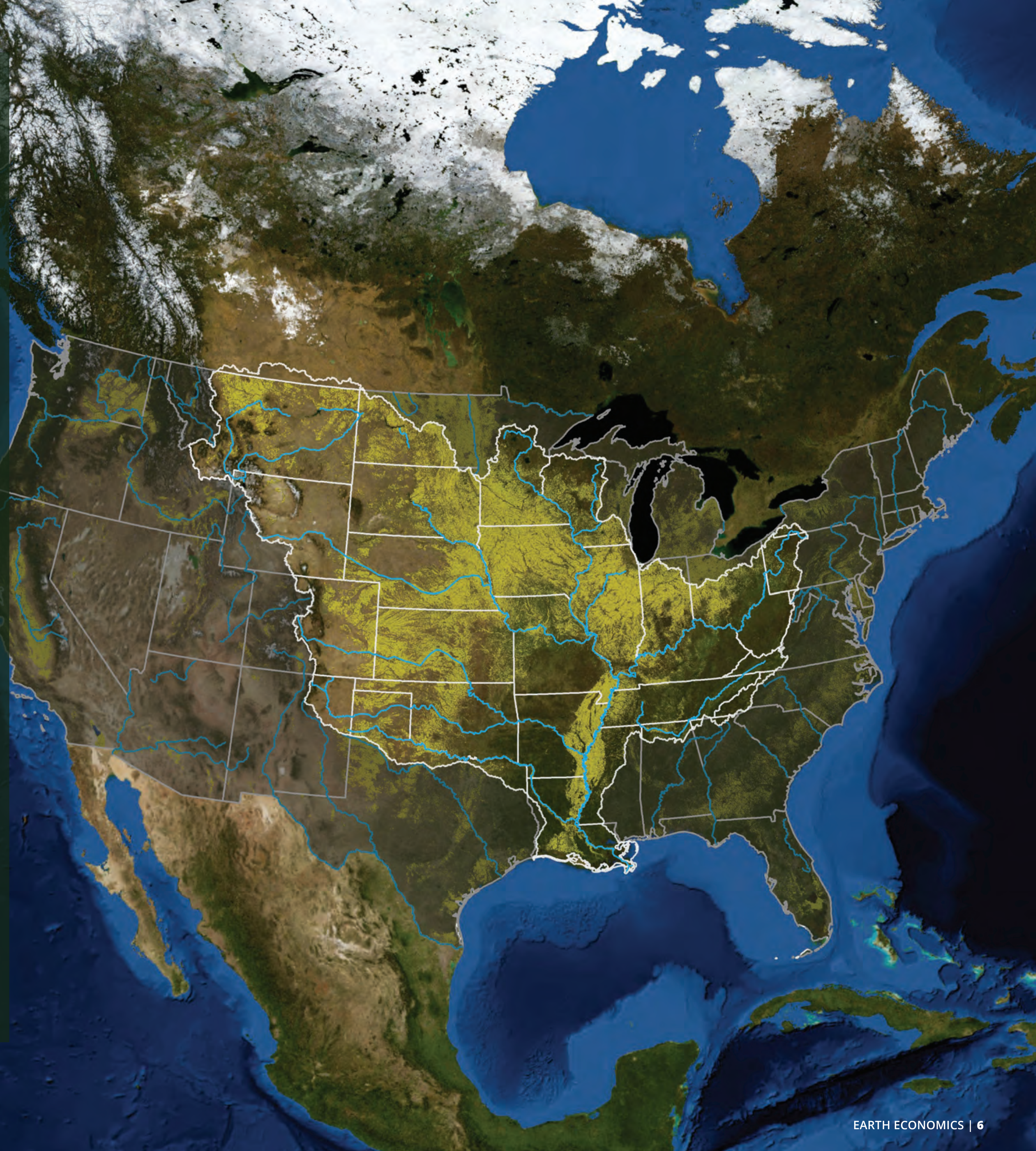
PURPOSE & STRUCTURE OF THIS REPORT

This report presents the land-cover change framework, one effective strategy for mainstreaming environmental costs and benefits into the benefit-cost analyses (BCA) conducted by the United States Army Corps of Engineers (USACE). Proper application of the framework depends on site-specific context, and this report uses the historical example of the Melvin Price lock and dam expansion project (hereafter, 'Melvin Price') on the Upper Mississippi River (UMR) to demonstrate the framework. The choice of Melvin Price is intentional, as it shares a similar ecological and land-use history with a large-scale infrastructure expansion project being considered today.

There are 29 locks and dams on the Upper Mississippi River that were originally built between 1917 and 1963. While most of the structures were rehabilitated in the 1980s to extend their usability beyond their 50-year life expectancy, the structures continue to age and require maintenance. Basic rehabilitation to keep the existing lock system functioning is stretched for funding (USACE, 2019a). The Navigation and Ecosystem Sustainability Program (NESP) of USACE is a long-term program tasked with the dual goals of implementing both navigational improvements and ecological restoration along the UMR (USACE, n.d.). NESP is considering expanding seven of the 37 locks on the Upper Mississippi River and Illinois Waterway (UMR-IWW) to bring them up to the current shipping industry standard of 1,200 feet in length.

The proposed NESP expansion — which is in the planning stage, awaiting funding — would significantly expand the navigation system along the UMR-IWW. This proposed expansion presents an opportunity for USACE to update its BCA best practices to include a systematic method for valuing environmental change that is compatible with its existing BCA process. Current USACE guidance dictates that environmental impacts that can be measured in dollars should be incorporated into BCA (WRC, 1983). The purpose of this report is to present a framework that will allow USACE to measure and include a wider variety of environmental impacts in its BCA. Quantifying the value of ecosystem services by analyzing changes in land cover will enable USACE to make decisions using the most complete information; under the current framework, most ecosystem impacts can only be measured in biophysical or qualitative terms. This report will demonstrate that the land-cover change framework is an effective way to incorporate environmental costs and benefits in the current USACE BCA process, thereby making the results more comprehensive and useful for decision makers.

To set the stage for presenting the framework, the report begins by reviewing the discipline of BCA and examines general best practices and methods. This review serves to identify areas of greatest opportunity for process modernization, especially concerning the valuation of environmental impacts in monetary terms. Next, the report focuses on the role that BCA plays in USACE decision-making, and specifically at how environmental costs and benefits are treated under current BCA guidelines. The next section provides important context on the ecology, industry, and mechanisms of land-cover change in the Upper Mississippi River. Finally, the report explains the land-cover change framework, demonstrates its application via the example of Melvin Price, and concludes with a brief discussion.



MAP SOURCES: ESRI, USDA

AGRICULTURAL LANDS

AN OVERVIEW
OF BENEFIT-COST ANALYSIS

Benefit-cost analysis (BCA) is a decision-making tool that is widely used by public agencies in the United States to help systematically understand the potential impacts — both positive and negative — of policy changes or projects. The power of BCA is that it translates impacts (e.g., changes in the number of jobs; or tons of freight moved by barge, train, or rail) into a common language: dollars. Expressing impacts in dollars facilitates the economic comparison of impacts that would otherwise be difficult to compare. The BCA process aims for rigor and replicability by drawing on a standardized set of valuation methods and best practices outlined by a robust academic literature and agency guidance across a variety of sectors and disciplines (e.g., FEMA, 2018; Boardman, Greenberg, Vining et al., 2017; Treasury Board of Canada Secretariat, 2007).

A benefit-cost analyis includes three basic steps:

- **STEP 1** Determine annual costs and benefits
- **STEP 2** Add over the lifetime of the project
- **STEP 3** Discount for future value adjustments

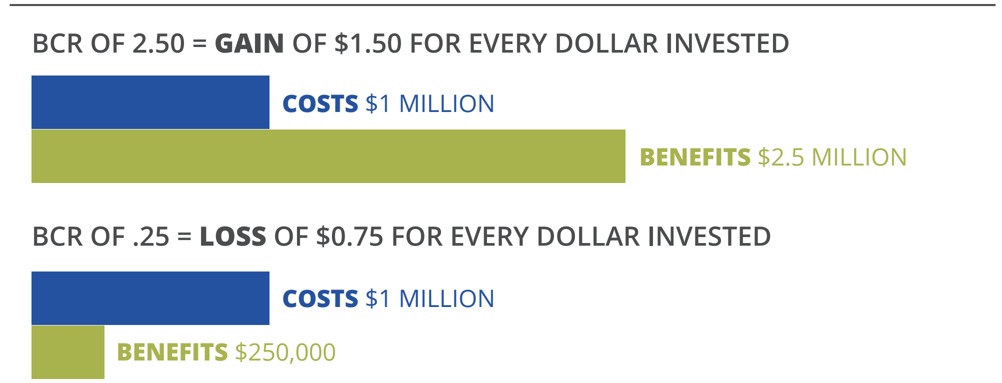
The goal of BCA is to provide objective, defensible, and replicable evidence of whether it is economically justifiable to carry out a project (i.e., whether benefits outweigh costs, and to what degree). In BCA, the costs and benefits are calculated over the useful life of the project and discounted to account for time preferences and the reduced value of money in the future, enabling the comparison of the net present values of the costs and benefits.

The end result of the myriad decisions regarding inputs, assumptions, forecasting, and discounting that make up the BCA process is a single number: the benefit-cost ratio, or BCR. This deceptively simple number — a distillation of so many complex choices — has a natural appeal for decision makers. This one piece of information also carries significant weight: investment decisions are hugely influenced by BCRs.

The simplest way to think about benefit-cost ratios is that projects with BCRs greater than 1.0 are economically justified, because benefits outweigh costs[1]. Federal projects yielding BCRs greater than 1.0 are typically passed on to the legislative and executive branches, which then can choose to appropriate funding. To mitigate uncertainty in the BCR related to accurately forecasting future costs and benefits, the Office of Management and Budget (OMB) defines a category high-performing projects that merit funding. This high-performing category represents those projects with BCRs that exceed a certain OMB-defined threshold even greater than 1.0 (GAO, 2010). Using this threshold creates a buffer by focusing on the projects with some margin of error — higher BCRs mean more certainty regarding the projected future costs and benefits. Examining the BCR allows project alternatives to be ranked according to which ones are expected to produce benefits most efficiently per dollar of investment — which is especially important, given limited government funding.

The decision to fund a project is heavily influenced by the BCR, which is one of the "... primary performance metrics for selecting which construction projects to propose for funding" (Carter, 2018, pg. 12). In fact, not all projects with BCRs exceeding 1.0 get funded. The current policy of the executive branch is to authorize the construction of all projects with a BCR greater than 1.0 (ibid.); however, the budget development threshold for the legislative branch to qualify a project for appropriations is a BCR greater than 2.5 (Carter and Nesbitt, 2016). In a report on the state of the federal BCA process, the American Society of Civil Engineers notes that limited budgets and a large number of authorized construction projects in the pipeline means that many of the authorized projects with BCRs below 2.5 are not considered for the budget, and they will be de-authorized by Congress if they do not receive funding within five years of authorization (ASCE, 2018).

FIGURE 1 RELATIONSHIP BETWEEN COSTS, BENEFITS, AND PROFIT



[1] *The benefit-cost ratio is derived by taking the net present value of the total benefits of a project, and dividing by the net present value of the total costs. As a general rule, the higher the BCR for a project, the better. To make BCRs more concrete, it is helpful to think about them not as ratios, but in terms of actual dollars. If a BCR is 1.5, that means that for every dollar invested in a project (the cost), it would return $1.50 in benefits; the return on investment would be $0.50 of profit for every dollar invested. Following the same logic, a BCR of 3.5 would yield $2.50 profit for every dollar invested, and a BCR of .25 would yield $0.75 in losses for every dollar invested (i.e., spend one dollar to get $0.25 in benefit).*

BENEFIT-COST ANALYSIS
METHODS & BEST PRACTICES

The following subsections explain the methods and best practices associated with conducting BCA. These subsections — Selection of Inputs, Assumptions and Forecasting, and Errors of Omission — correspond to three broad categories that largely dictate how a BCA will develop.

SELECTION OF INPUTS

The most important factor in shaping the results of a BCA is the list of costs and benefits that are valued by the analysis, and those that are not. BCA is naturally limited in the information it can provide by what can be quantified in monetary terms. In other words, only costs and benefits that can be measured in dollars will be included in the analysis. When data are not available, or costs and benefits cannot be translated realistically into dollar values, their impacts will be omitted from the analysis and thus the decision-making process. This includes impacts such as equity concerns or cultural values or loss of biodiversity. While this is an inherent limitation of BCA, it is important to note two things. First, the ability to understand and measure the economic impacts of a more comprehensive set of benefits and costs is constantly improving. This improvement is driven by improved access to quality data, greater technical capacity on the part of practitioners, improved valuation methods, and the mainstreaming of new considerations — such as ecosystem services — into BCA. Second, because conversations around public investment require the language of dollars and cents in order to compare options, it is critical to continue to measure impacts in economic rather than qualitative or biophysical terms whenever possible, so that the impacts can be properly accounted for in investment decisions. Because so many important decisions are made using benefit-cost analysis, practitioners should strive to understand, measure, and include an increasingly comprehensive set of values, so that decisions are made using the most complete information possible.

Benefit-cost analysis involves analyzing multiple project alternatives as well as a no-action scenario. This no-action scenario serves as a benchmark for interpreting the impacts of the project alternatives. The no-action scenario is "the most likely condition expected to exist in the future in the absence of a proposed ... project" (USACE, 2000, pg. 2-8). Examining the no-action scenario establishes a clear economic rationale for taking action to address the problem — if the analysis finds that taking no action would result in damages. If the no-action scenario results in no damages, it suggests that the problem is perhaps not as serious as first thought and that taking no action might be appropriate. However, if the analyzed options would result in even greater damages than taking no action, another suite of options would need to be identified and analyzed using BCA. Whatever the case, understanding the costs and benefits of doing nothing is essential to appropriately weighing proposed solutions.

A BCA must also account for the change in value of all benefits and costs associated with the project over its lifetime. For capital projects such as those built by USACE, BCA is conducted across a temporal horizon

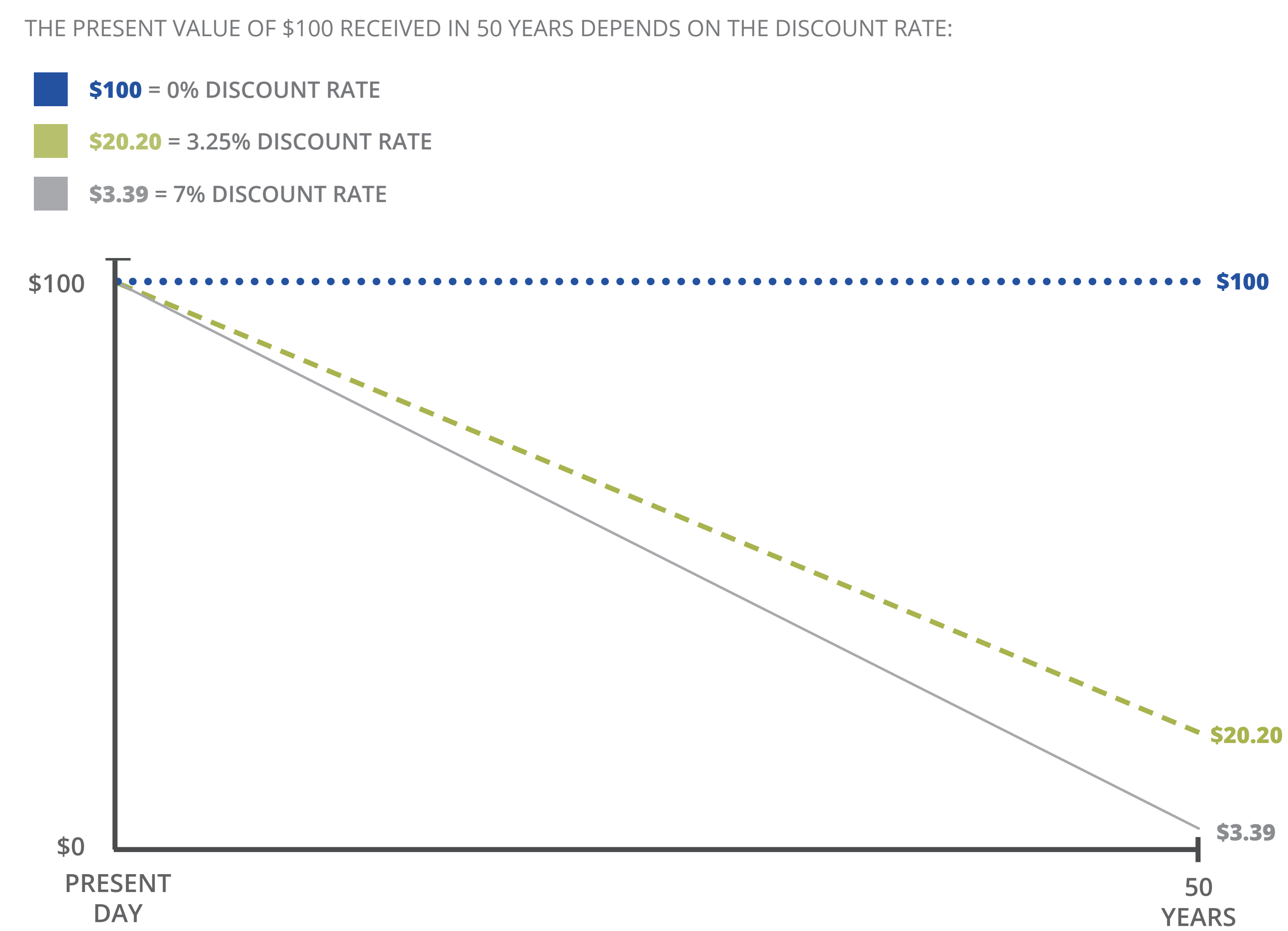
that reflects both the useful life of the project and the time at which adverse or beneficial impacts play out. The period of analysis for USACE projects will range from 20 to 100 years (USACE, 2014, pg. 1-3). For BCA conducted by USACE, the typical project will be analyzed over a 50-year period because forecasting beyond 50 years is not considered reliable (ibid.). The analysis begins at the year when the project is expected to begin construction and extends until the lesser of: 1) the period over which any alternative would have significant impacts; 2) a 50-year time horizon for non-major, multi-purpose reservoir projects; or 3) a 100-year time horizon for major, multi-purpose reservoir projects (USACE, 2000, pg. 2-11). Deciding on the appropriate period of analysis is a key input that affects BCA results. To account for this, a common practice is to model benefits and costs over multiple time horizons.

Discount rates are used in order to value the flow of costs and benefits over time. Discount rates are adjustments that account for two things: 1) People value present-day costs and benefits more than those that accrue in the future; and, 2) Money spent today could have generated more money if saved or invested. A higher discount rate means benefits and costs that will accrue in 20 years, for example, are valued less today. As the discount rate increases, future costs and benefits are devalued further; as the discount rate falls, they gain value.

Discounting requires a different way of thinking when considering the value of natural resources. This is because natural resources provide public benefits to society as a whole — for free. A healthy ecosystem is not a depreciating asset in the same way as traditional capital projects. With minimal investment, an ecosystem will continue to provide valuable services through the years, whereas anything made by humans will eventually wear out and require expensive repairs or replacement. Because of this, multiple generations can enjoy the benefits of healthy ecosystems. Discounting natural resources using the same logic as financial investments ignores this fundamental difference. Future generations will feel the loss of an asset (i.e., an ecosystem) that does not have a limited useful life more than one that will have to be replaced after a set period of time, like any built infrastructure. To account for this intergenerational consideration, the discount rate applied for analyzing natural resource values tends to be closer to 3 percent versus the traditional, market-based rate of about 7 percent.

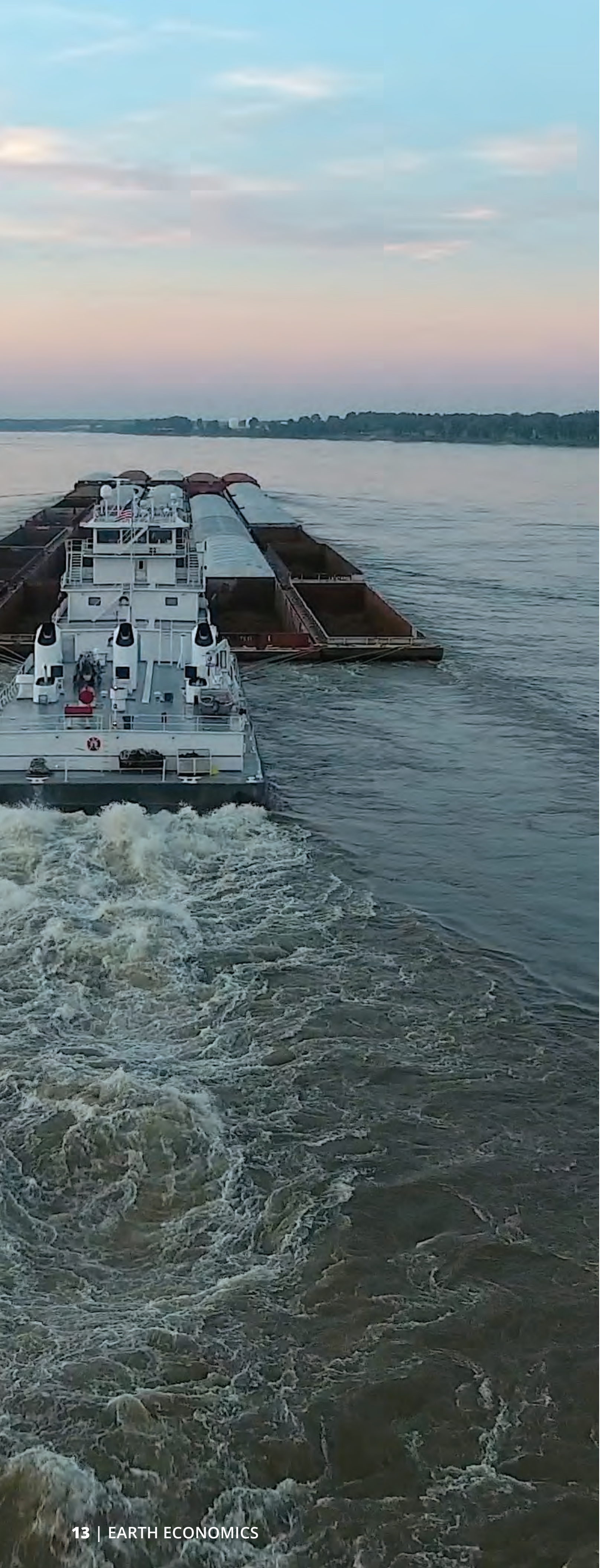
The selection of a discount rate is a key input that can significantly alter the results of a BCA. For example, $100 received in 50 years using a 0 percent discount rate is still $100 in the BCA. However, by increasing the discount rate to just 3.25 percent, the present value of $100 in 50 years would equal only $20.20. Discount rates are often based on market interest rates and generally range from 2 percent to 7 percent. The federal Office of Management and Budget suggests a discount rate of 7 percent, which represents the pretax rate of return on an average investment in the private sector (OMB, n.d.). For fiscal year 2019, USACE recommends a 2.75 percent discount rate for water resource projects (USACE, 2017). Ultimately, selecting the discount rate is a policy choice, one that is informed by both values and economic theory.

FIGURE 2 CALCULATING THE PRESENT VALUE OF FUTURE RETURNS: A STYLIZED COMPARISON OF DISCOUNT RATES



A primer produced by USACE describes the BCR in simple terms:

> “A benefit-cost ratio allows dissimilar projects to be compared. It shows which investments give ‘the most bang (benefits) for the buck.’ ”
>
> Durden and Fredericks, 2009, pg. 18



ASSUMPTIONS AND FORECASTING

All BCA relies on a set of assumptions made by the analysts. It is often necessary to fill gaps with predictions if no data exist for key inputs. The quality of these projections will vary naturally; predicting the future is a difficult, uncertain exercise. When project costs and benefits are forecasted over time, the effects of the underlying assumptions are compounded, underscoring how critical it is for them to be as accurate and comprehensive as possible.

To illustrate how assumptions affect the forecasts of future costs and benefits, it is helpful to consider a stylized example. The costs and benefits of a proposed lock expansion project are to be analyzed over a 50-year period, and the analysis starts out with highly positive agricultural commodity and traffic projections. The effects of these assumptions compound across the 50 years, and the effects over time can be astronomical. Even a small initial over-projection will result in unrealized benefits that add up every year over the period of analysis, resulting in a significantly lower benefit-cost ratio than initially forecasted. The longer the relevant period of analysis, the greater the difficulty in forecasting. Most BCA extends far into the future, which adds the additional challenges of forecasting changes in the global economy and environment, as well as how much to value the impacts on future generations. To account for these challenges inherent in forecasting, it is important to vary the projections for key inputs using sensitivity analyses and to scrutinize the information that informs their underlying assumptions. It is paramount that such due diligence and standardization be adopted at the start of the process to ensure that assumptions are prudent, and that assumptions are regularly revisited and compared against observed data, so that forecasting methods can continue to improve.

ERRORS OF OMISSION

Important costs and benefits are often omitted from BCA. As noted already, impacts that cannot be assigned a dollar value will not be captured in BCA. Costs and benefits that can be measured in dollars are also commonly omitted. In particular, the value of natural capital assets is frequently underrepresented or altogether left out of such analyses.

Natural capital refers to the planet's stock of natural resources, or assets. This includes Earth's geology, chemistry, soil, water, air, flora, fauna, bacteria, and fungi. Forests, watersheds, mountains, and shorelines represent natural capital assets. These assets contain multiple ecosystems that perform a variety of ecosystem functions. These functions in turn provide beneficial services that enrich the human experience, such as water filtration, raw material production, flood risk reduction, recreation, climate regulation, and more. As natural capital degrades, ecosystem functions are impaired and the value of ecosystem goods and services that humans receive decreases.

Ecosystem services — breathable air, drinkable water, fertile soils, disaster resiliency — are critical to human survival. When these services are lost, the economic impacts can be measured in a variety of ways, including adverse health impacts, decreased productivity, and property loss. In recent decades, considerable progress has been made in systematically linking functioning ecosystems with human well-being. Typologies created by De Groot, Wilson, and Boumans (2002), the Millennium Ecosystem Assessment (MEA), and The Economics of Ecosystems and Biodiversity (TEEB) have all established conceptual models for valuing natural capital and ecosystem goods and services. These models have allowed BCA practitioners to account for the cost of environmental impacts in more comprehensive and systematic terms. Earth Economics uses a hybrid model based on these three sources. This model counts 21 ecosystem service categories that can be translated to dollar values for economic analysis – see Appendix A for details.

The inclusion of ecosystem service values in BCA is gaining significant traction at the federal policy level as the understanding of the value of natural capital — and how to measure it — improves. In 2013, the Federal Emergency Management Agency (FEMA) announced a landmark policy change that allowed ecosystem services to be included in the formal BCA process for flood risk mitigation projects (FEMA, 2013). In 2017, FEMA released BCA Toolkit Version 5.3.0, which provides explicit guidance for including ecosystem service values in BCA, doubles the number of ecosystem service values from the prior version, and extends the application of ecosystem services beyond flood risk mitigation to all FEMA project types (FEMA, 2018).

FEMA is not alone in this work. The U.S. Department of Housing and Urban Development required ecosystem service values to be included in the BCA conducted by finalists for their 2015 National Disaster Resilience Competition (HUD, 2015). In October that year, the Executive Office of the President issued a memorandum requiring all federal agencies to develop policies to promote the consideration of ecosystem services in their decision-making process (Donovan, Goldfuss, and Holdren, 2015). Including ecosystem service values is quickly becoming a standard best practice for BCA at the federal level.

Proper consideration of these values ultimately strengthens decision-making. When natural capital and ecosystem services are not quantified, they are effectively valued at zero in the decision-making process. This leads to inefficient investments based on incomplete information that translates to higher future costs and poor asset-management strategies. The dynamic complexity of most ecosystems — and the range of ecosystem goods and services they produce — makes it exceptionally difficult to substitute or replace these with human-made infrastructure and technology. The short-term gains from activities that degrade or destroy ecosystem function are often dwarfed by the lost long-term economic value of functional ecosystems (Guyon, Deutsch, Lundh, and Urich, 2012). Translating the real-world benefits that ecosystems provide into dollars and ensuring that these values are properly accounted for in planning decisions is an often overlooked but growing best practice for practitioners of BCA.

BENEFIT-COST ANALYSIS AT **U.S. ARMY CORPS OF ENGINEERS**

The use of BCA dates back to the Flood Control Act of 1936, which made navigation and flood-control projects a priority of the federal government and required evaluating these projects in terms of their projected costs and benefits (National Research Council, 2004; Persky, 2001; Dorfman, 1978). Guidance for BCA has developed through the years, and USACE currently follows the methods and best practices outlined by two documents: the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (hearafter, ‘Principles and Guidelines’) that guides all federal agencies for water projects (WRC, 1983) and the Planning Guidance Notebook developed specifically for USACE that expands upon the Principles and Guidelines (USACE, 2000). These documents include guidance on the selection of inputs, the treatment of uncertainty, the temporal horizon of a project, how to present results, and many other prescriptions. Even as the implementation guidance has evolved over the years, one constant is that BCA has been the most important tool for USACE in analyzing water resource projects (National Research Council, 2004).

THE ROLE OF BCA IN **USACE DECISION MAKING**

In order to understand how BCA fits into project planning and decision-making, it is important to review the four decision-making accounts that USACE uses to evaluate projects. When evaluating a project, USACE considers benefits and costs from different perspectives — these are the four “accounts.” First in the hierarchy is the NED account, which measures the net economic benefits to the nation. The NED account falls within the purview of BCA. The Principles and Guidelines clearly outlines the primacy of the NED account in decision-making, explaining that the federal government’s objective is to select “the alternative plan with the greatest net economic benefit consistent with protection of the Nation’s environment (the NED plan) ...” (WRC, 1983, pg. 15). The clause about protecting the environment is not a proactive prescription to weigh the entirety of environmental costs and benefits of a project; rather, environmental protection simply is “... provided by mitigation of the adverse effects ...” (WRC, 1983, pg. 7) of a proposed plan. Simply put, if a BCA finds a benefit-cost ratio greater than 1.0 after accounting for mitigation costs, a project is justified on national economic development grounds.

Once a positive national economic benefit has been established, a project can then be considered from other perspectives: the RED — regional economic development — account; the EQ — environmental quality — account; and, the OSE — other social effects — account.

While national economic benefits are measured in NED, regional economic benefits are measured in RED. The RED account, like NED, measures the transfers of economic activity in dollars, but from the perspective of changes within a region or from region to region using input-output analysis (Bushnell and Knight, 2011). Usually, major infrastructure projects like those pursued by USACE will result in both national and regional economic benefits. Regional benefits can best be described as transfers from one part of the country to another; an example is a new levee that offers flood risk reduction benefits and draws businesses away from other high-risk areas to the area protected by the levee, thereby moving regional economic activity and additional tax revenue from one location to another. A USACE primer describes the difference between NED and RED benefits:

“From the federal perspective transfers are a zero-sum game. That does not mean that RED benefits are not significant or important to the non-federal partner. The distinction between NED and RED is a matter of perspective and policy, not economics” (Durden and Fredericks, 2009, pg. 6).

The EQ account “... shows effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be measured in monetary terms” (WRC, 1983, pg. 8). These EQ attributes are described by the Principles and Guidelines as those that “... sustain and enrich human life” (WRC, 1983, pg. 103). Analyzing the effects in the EQ account, as with the NED account, is required as part of the decision-making process (USACE, 2000).

The OSE account has a broad mandate to capture the effects not studied by NED, RED, or EQ (USACE, 2000). OSE is most useful for identifying project alternatives during the initial planning stages rather than selecting the preferred option between them (Dunning and Durden, 2009). The Planning Guidance Notebook identifies categories of effects that fall under OSE: “Urban and community impacts; life, health, and safety factors; displacement; long-term productivity; and energy requirements and energy conservation” (USACE, 2000, pg. D-39). As recently as 2013, including OSE analysis as part of USACE water resource planning was not required (Durden and Wegner-Johnson, 2013), but its importance is gaining recognition as USACE moves toward a more holistic evaluation method of all four accounts.

The Principles and Guidelines provides only recommended guidance and is not legally binding; this contrasts with the Principles and Standards of 1973 — the document it replaced — which offered binding planning requirements (National Research Council, 2004). Adoption of the Principles and Guidelines renewed the focus of federal government agencies on a single goal of pursuing project alternatives that maximize net national economic development, placing the NED account at the center of USACE decision-making (Knight, 2008). Criticism of the Principles and Guidelines has centered on "the document's narrow focus and its failure to adequately incorporate nonquantifiable environmental and social impacts into its planning steps" (National Research Council, 2004, pg. 20). Though the Principles and Guidelines provides "great latitude to include [the] four accounts, [it] does not force planners to use them" (Knight, 2008, pg. 3). Because of the relative importance of the NED account in the decision-making hierarchy, many times the other accounts are effectively overlooked in USACE decision-making (National Research Council, 2004).

Recent additional guidance has been issued that attempts to guide USACE best practices away from its NED-centric focus toward "… more holistic, inter-governmental and inter-sector solutions …" via greater consideration of all four accounts (Knight, 2008, pg. 1). Engineer Circular 409 (EC 409) provides the philosophical underpinnings for expanding USACE decision-making criteria to more equally involve all four accounts in decisions (USACE, 2005). Specifically, it states that "… all Corps planning studies will evaluate, display and compare the full range of alternative plans' effects across all four Principles and Guidelines' accounts" (USACE, 2005, pg. 4). However, this guidance exists in conflict with the current mandate of the Principles and Guidelines to maximize net national economic benefits in NED (Knight, 2008). This results in a difficult-to-reconcile gray area, a tug-of-war between the NED-first mandate of the Principles and Guidelines (WRC, 1983) and the recent push by USACE to integrate environmental costs and benefits into its analysis (e.g., CEQ, 2013). This is a challenge that USACE is working to resolve via updates to its Planning Guidance Notebook and the Principles and Guidelines, and through additional engineer circulars and white papers.

USACE is continuing to pursue a more integrated evaluation of costs and benefits across all four accounts. Though EC 409 was written in 2005, the USACE Planning Community Toolbox — updated in 2019 — indicates that rather than being expired or obsolete, EC 409 "will be incorporated into permanent guidance" (USACE, 2019c). The lag between the creation of EC 409 and its formal integration with the primary guidance documents speaks both to its importance and the practical hurdles involved with systematically integrating the four accounts in decision-making. One incremental step toward including all four accounts in USACE decisions is to incorporate ecosystem service values into the NED account and by extension, BCA.

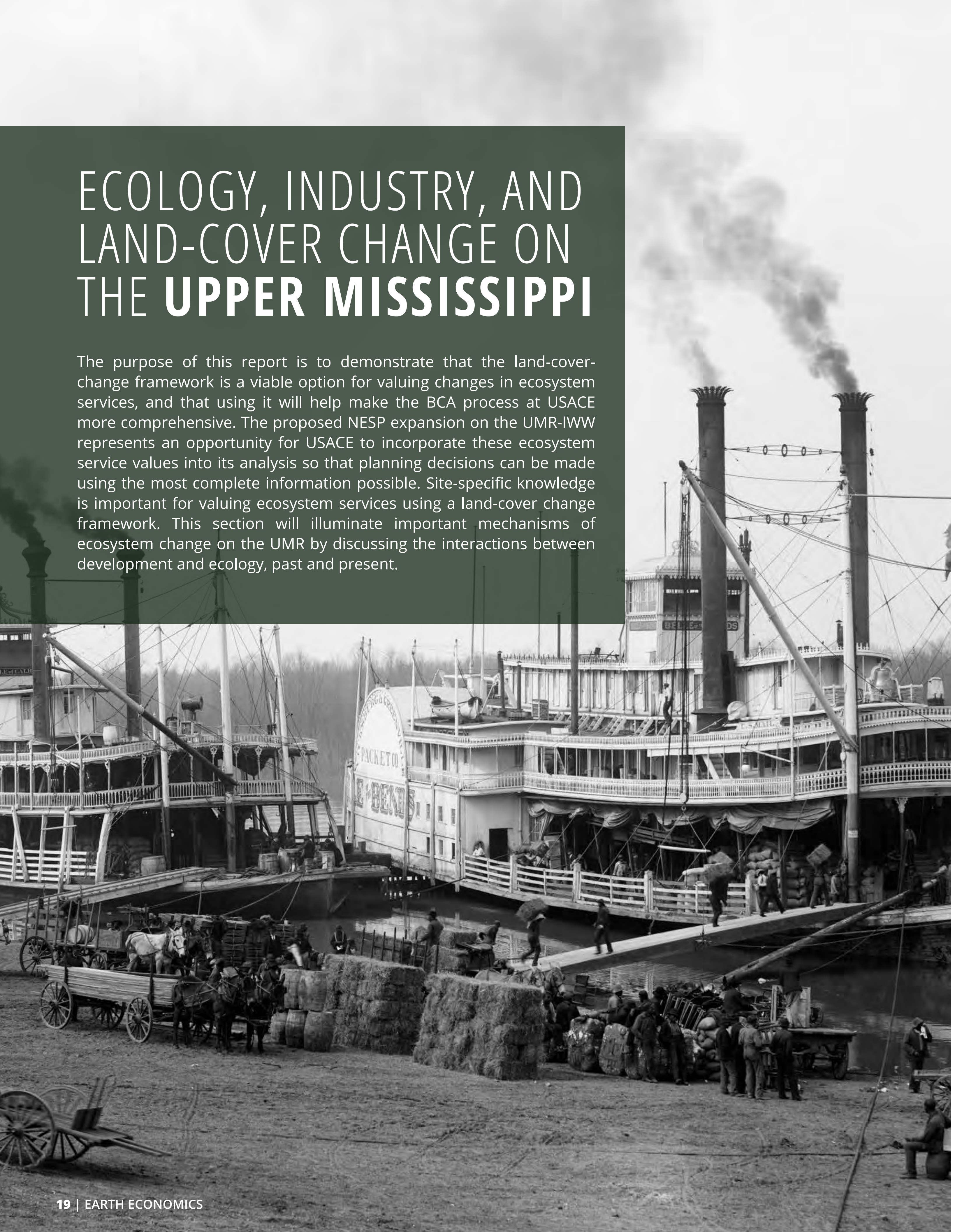
ENVIRONMENTAL COSTS AND BENEFITS IN **USACE DECISIONS**

The Principles and Guidelines indicates that environmental changes that can be measured in monetary terms belong in the NED account (WRC, 1983). In practice, however, the lack of explicit guidance for how to value environmental changes means that monetizing these impacts is rarely performed, relegating environmental costs and benefits to the EQ account. In the EQ account, costs and benefits are only addressed qualitatively or in biophysical terms (USACE, 2000) and, by virtue of not being measured in dollars, they do not factor into the benefit-cost ratio that informs whether a project is given the go-ahead.

The ecosystem service framework presented in the Errors of Omission section makes it possible to measure a broad array of environmental impacts in dollars and include them in NED. The omission of environmental impacts — both positive and negative — from the NED account means that high-dollar decisions are made using incomplete information, reducing the certainty that selected projects are actually maximizing the returns on public investment. Measuring environmental changes in dollars wherever possible is a best practice, but it needs systematic guidelines for mainstreaming it into the BCA methodology used by USACE.

A recent report by the White House Council on Environmental Quality outlined proposed changes to the federal Principles and Guidelines and the Planning Guidance Notebook. This report aligns with the intent of USACE to systematically incorporate environmental costs and benefits into its BCA process. The proposed revisions highlight the need to protect naturally occurring ecosystem services, stating that "healthy and resilient ecosystems not only enhance the essential services and processes performed by the natural environment, but also contribute to the economic vitality of the Nation" (CEQ, 2013, pg. 4). The report also acknowledges practical advancements in ecosystem service valuation techniques and seeks to make ecosystem service valuation a required part of BCA (ibid.). However, USACE adoption of the changes has been prohibited through recurring language in the annual federal appropriations bills (e.g., H. Rep. No. 113-486, 2015), and the lack of unifying and explicit guidance persists today.

USACE has been moving toward more collaborative assessments that serve to better integrate the four different accounts, and the economic valuation of environmental impacts is a key step in this direction. Measuring a greater number of environmental impacts in monetary terms would expand BCA to include a broader understanding of impacts, ultimately leading to more multi-benefit and efficient investment decisions. Valuation would not replace the EQ account since many environmental impacts cannot be translated easily into dollar values, but it would expand the boundaries of the economic assessment, improve the robustness of the current methodology, and increase the validity of the BCA results. Moreover, in the face of increasingly scarce resources — both natural and institutional — there is a stated push to view navigation projects as multi-purpose projects where ecological restoration and navigation can be pursued as parallel objectives in order to spend time and money more efficiently and maximize public benefits. As USACE continues to plan infrastructure improvements that enable navigation on the UMR, the need to integrate ecosystem impacts into planning decisions is becoming increasingly apparent.



ECOLOGY, INDUSTRY, AND LAND-COVER CHANGE ON THE **UPPER MISSISSIPPI**

The purpose of this report is to demonstrate that the land-cover-change framework is a viable option for valuing changes in ecosystem services, and that using it will help make the BCA process at USACE more comprehensive. The proposed NESP expansion on the UMR-IWW represents an opportunity for USACE to incorporate these ecosystem service values into its analysis so that planning decisions can be made using the most complete information possible. Site-specific knowledge is important for valuing ecosystem services using a land-cover change framework. This section will illuminate important mechanisms of ecosystem change on the UMR by discussing the interactions between development and ecology, past and present.

HISTORY

In 1820, a vessel called the Western Engineer completed the first steamboat journey on the Upper Mississippi River (O'Brien, Rathbun, and O'Bannon, 1992); nine years earlier, the first steamboat made the trip from Pittsburgh down the Ohio River to its juncture with the Mississippi, and followed it all the way down to New Orleans (Alexander, Wilson, and Green, 2012). Navigation was a challenge in those days, as boats had to pilot past accumulated woody debris, intermittent shallow sand bars, and the varied currents and rapids that are the hallmarks of a free-flowing, meandering river system. Since that time, the UMR has been extensively engineered to promote ease of navigation and the shipping of agricultural exports from America's breadbasket. Today, boats move freely via a system of locks, dams, and other structures designed to ensure a consistently deep, straight, and dependable channel. While this transformation has greatly simplified navigation and brought greater wealth to the area, it has fundamentally altered the structure and function of the ecosystems along the UMR (ibid.).

Economic activity along the Mississippi River has been impacting its ecology for centuries. From the extensive deforestation spurred by increased steamboat traffic at the turn of the 19th century to runoff from modern-day concentrated animal feeding operations (CAFOs), human settlement and economic development have altered and degraded river functions. Much of this change was driven by federal regulation. The Swamp Lands Act of 1850 transferred control of wetlands from the federal government to the states for the explicit purpose of reclamation and development, setting the stage for enormous quantities of wetland in the Mississippi River Basin to be converted to farmland over the next 100 years (Dahl and Allord, 1996). Up until the end of the 19th century, the creation of levee and drainage districts allowed private landowners to dredge and channelize streams, install drainage tiles, and construct levees. After World War II, large-scale, chemically dependent monocrops — recognizable as the industrial farms of today — came to dominate the Mississippi River Basin ("Industrial Agriculture", n.d.). This massive conversion of wetland to farmland precipitated an agricultural boom that brought significant wealth to the area, as well as ecosystem changes and degradation of the river and surrounding watershed.

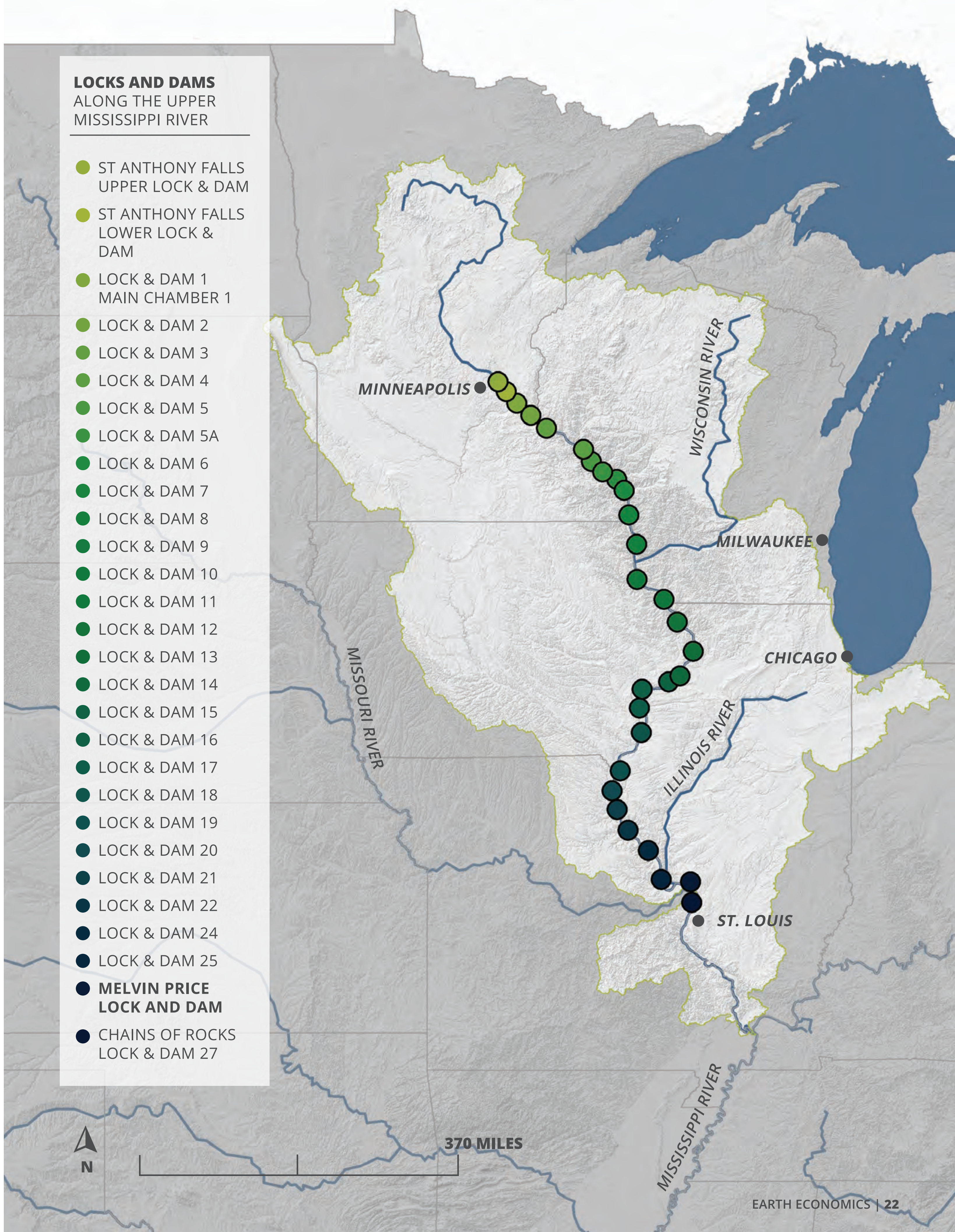
PRESENT DAY

The Mississippi River travels some 2,300 miles from its headwaters in Lake Itasca to the Gulf of Mexico and is the second-longest river in North America (National Park Service, 2018). Its watershed drains about 40 percent of the continental U.S. and is the fourth-largest watershed in the world (ibid.). It is one of the most important ecosystems in the country, transporting water, sediment, and nutrients throughout its course and providing habitat for fish and wildlife. Its riparian areas and floodplains improve the quality of both groundwater and surface water, filter and cycle nutrients, reduce the severity of floods, protect wildlife, and recharge groundwater supplies. Plant communities sustained by the river produce critical habitat for fish and wildlife, sequester and store carbon, build soils, and improve soil quality by converting sunlight and nutrients into organic matter. Natural areas along the river provide habitat for beneficial insects that pollinate nearby crops, and the manure of migratory waterfowl enriches the soil. Fish and their habitat support valuable commercial and recreational industries.

In addition to providing ecosystem services, the river sustains an enormous volume of economic activity in the area. Agribusiness and the shipping industry are deeply intertwined in the Mississippi River Basin. Agriculture has been the primary land use for 200 years in the area and the shipping industry moves 60 percent of all grain exported from the U.S. downriver through the ports of New Orleans and South Louisiana (National Parks Service, 2018). These two industries serve as the foundations of human settlement and economic development along the river. Today, the industrial agriculture and fossil fuel industries are the primary drivers of the barge industry, accounting for approximately 70 percent of freight (USACE, 2018).

The ecosystems of the UMR have been dramatically altered by the construction of 29 locks and dams, 3,000 miles of levees, extensive and repeated dredging, development of floodplains that severs the interconnected hydrology of the river, and concrete revetments that lock the banks in place (USACE, 2019b). The UMR of today is highly modified by built infrastructure that prevents it from performing many of its natural ecological functions. Many of the reductions in ecological functioning along the UMR stem from a loss of connectivity across the ecosystem due to ecological fragmentation and habitat loss, alterations to sediment and nutrient balances, and water quality changes due to navigation and water flow disruptions. Other factors contributing to the disrupted ecological functioning of the river are the conversion of native prairies to cropland and the destruction of bottomland forests in the surrounding lands of the Mississippi River Basin. As these native ecosystems continue to be altered or degraded, so are the many valuable services they provide.

The Long Term Resource Monitoring Program was established in the 1980s as part of a federally mandated restoration program for the UMR to understand and track environmental problems in the region. A report from 2008 conducted as part of this program asserted that the engineering solutions that enable navigability — dams, channel training structures, and dredging in particular — negatively impact the health of the river (Johnson and Hagerty, 2008). Impacts attributed to these causes include high rates of erosion and sedimentation in backwaters and side channels, islands lost to the main channel in impounded zones of the river, a loss of hydrological connection between the floodplain and the river, and the presence of invasive, non-native species (ibid.).



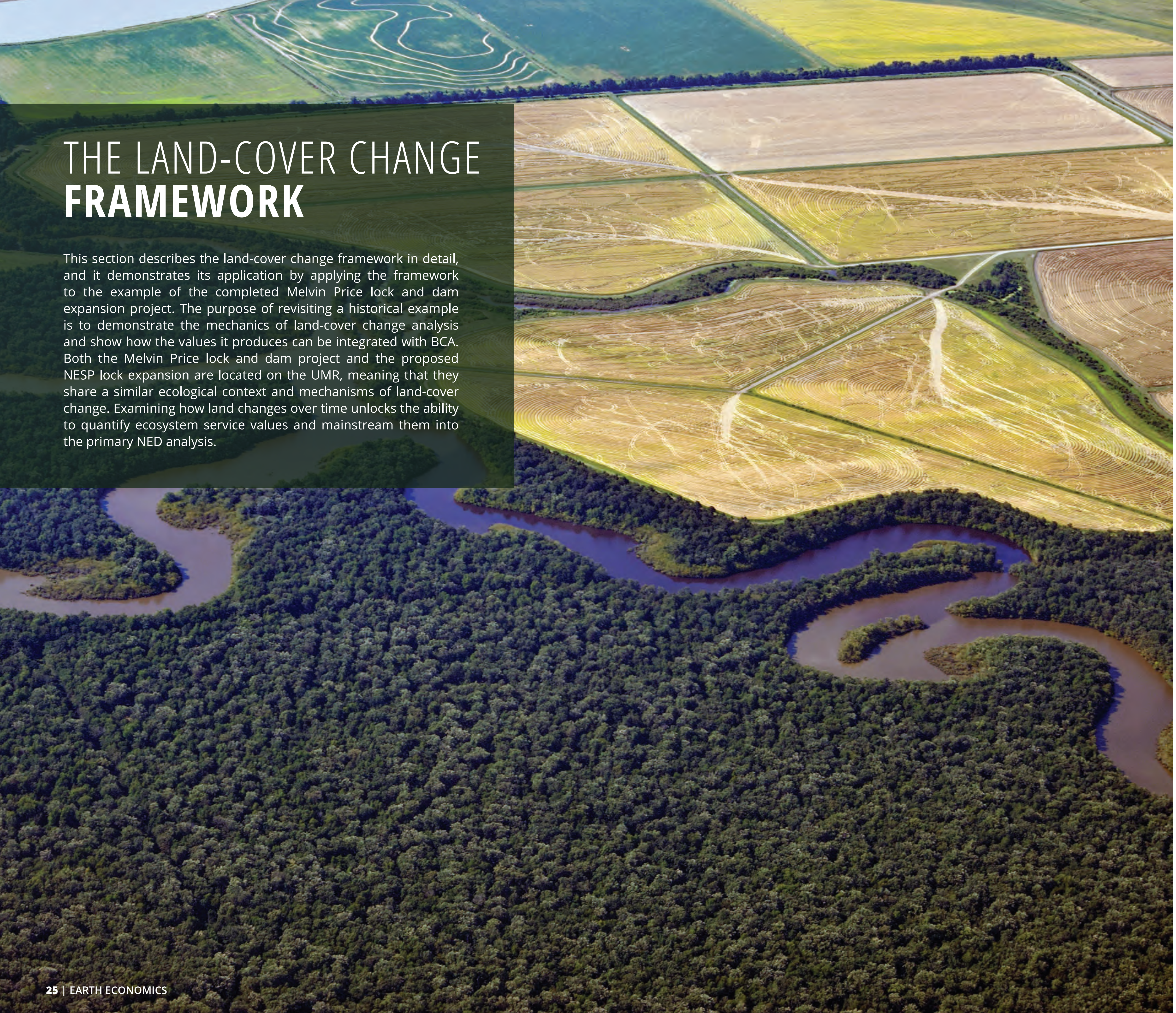
A free-flowing river system is highly dynamic and interrelated, balancing system needs by dispersing water, sediment, and nutrients across the watershed. Adding locks, dams, and other engineered solutions to the river adds more change on top of an already changing system. Precisely identifying which actions cause which effects in the watershed is difficult, if not impossible, but USACE documentation and the best science available agree that human alterations of the river are major ecological stressors (USACE, 2016; National Research Council, 2005). The National Research Council report offers a simple description of the impact of all this engineering: "[It has] disrupted the natural, seasonal ebb and flow of waters that help sustain the diversity of plant and animal life along the river" (2005, pg. 2). Figure 3 describes how locks and dams change the hydrology of the river as well as the resulting changes to the ecosystems and ecosystem services along the UMR.

The infrastructure and engineering solutions that allow the river to be navigable (e.g., locks, dams, river training structures, levees, revetments, riprap, and dredging) constitute major ecological stressors that change the river in complex ways. Changing the shape of the river also changes the way the river distributes nutrients, deposits sediments, creates and erodes land, and provides habitat for fish and wildlife. This has produced unintended consequences, and despite extensive efforts to restore the ecosystems of the Upper Mississippi, degradation continues. A report of the USACE Upper Mississippi River Restoration Program is blunt in its assessment of the health of the river's ecosystems: "... the existing and new stressors on the system will continue to cause degradation. Fish and wildlife habitat has been declining in quantity, quality, and diversity for decades, at an estimated degradation rate of one to three percent annually. What this means is, at these rates, the ecosystem is declining at one to four times faster than it is being restored" (USACE, 2016, pg. iii-iv).

Ecology and industry along the Mississippi have long existed in a state of give and take. The value of the natural capital of the river itself enabled early industry — farming, shipping, manufacturing — to create economic wealth throughout the Mississippi River basin. At the same time, this development degraded the river, thereby impairing the function and value of the natural river that initially enabled industry to develop and flourish. These unintended consequences of developing the UMR are better understood in the modern day, but the losses in natural capital resulting from that development have yet to be sufficiently accounted for in long-term planning decisions. One way to highlight the critical tradeoffs between ecology and industry is to include ecosystem service values in benefit-cost analysis — the primary tool that guides USACE infrastructure investment decisions. Including the most comprehensive set of benefits and costs in the BCA process would help identify solutions that yield efficient returns on the investment of public dollars and result in more widespread benefits.

FIGURE 3 IMPACTS OF LOCKS AND DAMS ON ECOSYSTEM SERVICES

ECOSYSTEM SERVICE	IMPACT	DESCRIPTION
FOOD	Indeterminate	Elevation of the surrounding groundwater table may be raised or lowered by lock and dam operations, which may affect crop yields.
	Cost	Prior to large-scale river engineering, seasonal floods deposited nutrient-rich sediment throughout the floodplain. Disrupting this process has reduced the native fertility of soils throughout the floodplain.
ENERGY AND RAW MATERIALS	Benefit	Only three UMR dams have hydroelectric turbines (LD1, LD19, and Lower St. Anthony Falls).
	Cost	The reservoirs formed by locks and dams may restrict access to sand and gravel pits along the river.
WATER STORAGE	Benefit	Surrounding groundwater tables are often raised by pools and their enabling structures, levees, and dams.
BIOLOGICAL CONTROL	Indeterminate	Dams affect movement of both native and invasive aquatic species.
CLIMATE STABILITY	Cost	Carbon sequestration, storage, and greenhouse gas releases are determined by ecosystem processes tied to water and land-cover types and conditions. Reservoirs can be significant sources of methane and nitrous oxide emissions, which increase with ambient temperatures.
DISASTER RISK REDUCTION	Benefit	Restricting the river course with levees, dams, and other control structures increases the potential for large flood events.
SOIL FORMATION	Cost	Control structures alter the natural movement of sediment through the Mississippi, increasing land loss downstream and increasing sedimentation in pools and back channels. Control structures increase sediment, organic matter, and phosphorous in reservoir benthic zones, while filling in backwater streams, impacting habitat and food sources for both fish and migratory waterfowl.
SOIL QUALITY	Cost	Control structures restrict the Mississippi's capacity to improve soil quality across large stretches of land through flooding. Meanwhile excess nutrients flowing to the Delta are creating dead zones in the ocean.
SOIL RETENTION	Cost	Navigation and large barge traffic contribute to river bank and shoreline erosion, as well as riverbed scouring in the main channel.
WATER QUALITY	Cost	Reduced flow and change in water temperature added to loss of vegetated riparian areas can degrade water quality.
NAVIGATION	Benefit	Dams and levees confine and narrow rivers, to maintain water levels for navigation. Coupled with locks and dredging of the authorized channel, these systems enable year-round traffic up and down the river.
HABITAT AND BIODIVERSITY	Cost	Control structures change water levels in back channels, reducing submerged aquatic vegetation, a food source for migratory waterfowl and habitat for fish.
	Cost	Control structures impact river flow, influencing the abundance and diversity of both native and invasive aquatic and terrestrial species.
RECREATION	Benefit	The pools created by control structures are enjoyed for boating, fishing, and sightseeing.
	Cost	Some recreational areas and habitat may be eliminated as a result of inundation caused by navigation expansion, free flow navigation, and wildlife viewing impacted.



THE LAND-COVER CHANGE **FRAMEWORK**

This section describes the land-cover change framework in detail, and it demonstrates its application by applying the framework to the example of the completed Melvin Price lock and dam expansion project. The purpose of revisiting a historical example is to demonstrate the mechanics of land-cover change analysis and show how the values it produces can be integrated with BCA. Both the Melvin Price lock and dam project and the proposed NESP lock expansion are located on the UMR, meaning that they share a similar ecological context and mechanisms of land-cover change. Examining how land changes over time unlocks the ability to quantify ecosystem service values and mainstream them into the primary NED analysis.

PURPOSE

Land-cover change analysis is performed by identifying and categorizing land-cover types, measuring how they change over time, and valuing those changes in monetary terms by mapping them on to the ecosystem service framework (see the Errors of Omission section of this report). When land is converted from one type to another, ecosystem functions are altered, changing the suite of ecosystem services provided. This change is critical to measuring the impacts of proposed navigation projects and is the basis of the framework for evaluating costs and benefits in a more comprehensive, modernized manner.

LIMITATIONS

One challenge of the framework is that analyzing ecosystem services based on land-cover type is limited by how the land-cover types are defined and whether variation within generalized types (e.g., woody wetlands versus herbaceous wetlands) produces significant differences in ecosystem function and productivity. Performing these comparisons is limited further by the availability of data on land-cover change and condition of land cover (e.g., data that help identify the degree to which the area adjacent to the river is deforested). This challenge of the framework will impact the results in variable ways, depending entirely on the data available and how the analysis opts to define the land-cover types.

Another challenge (discussed at length in the Errors of Omission section of this report) is the inherent difficulty of measuring in dollars the entirety of an ecosystem's contribution to human well-being. It is often the case that impacts to multiple ecosystem services will be recognized, but only some services will have adequate data and methodological guidance to enable measuring the impacts. This particular challenge of the land-cover change framework will typically result in an underestimate of the monetary impacts, leaving the impacts that cannot be valued in dollars to be treated in qualitative or biophysical terms in the EQ account.

A final challenge is precisely attributing environmental impacts to their causes. The complex interaction of human actions and ecological dynamics in the UMR-IWW can make it difficult to isolate the effect of a single project embedded in a larger system. In a perfect world, the analysis of the Melvin Price lock and dam (and the proposed NESP expansion) would identify the impacts that can be attributed solely to the project, excluding all other mechanisms of environmental change. Precisely attributing impacts to specific sources is a nearly impossible task, given the vast scale of the river system's drainage basin and the complexity of the ecological interactions therein, together with the knowledge that Melvin Price is just one of dozens of other locks and dams (and hundreds of levees and dikes) along the river. This limitation in assigning impacts to specific projects is compounded by the relative scarcity of geospatial data for the impounded reaches of both the Mississippi River and Illinois River, especially over time. Attributing 100 percent of identifiable land-cover changes to a single project could overstate the impacts; however, this uncertainty can be mitigated by presenting a range of less aggressively attributed impacts (i.e., applying weight factors to scale down, and showing results for, as an example, 60 percent, 80 percent, and 100 percent attribution), or by consistently adopting conservative assumptions throughout the remainder of the analysis. Rather than scaling down impacts via weight factors, this analysis opted for a conservative approach, eliminating certain types of land cover conversions whose values were not attributable to the project in question (e.g. converting agricultural land to developed land). Additionally, ecosystem service valuation typically cannot measure every ecosystem service in dollars, due to limitations in data availability or methodological challenges. As such, valuing ecosystem services inherently presents an underestimate of the total value provided; to some degree, this offsets the overestimate of 100% attribution in a complex system.

Because of these limitations, the following section does not directly address habitat quality or floodplain connectivity, nor does it attempt to parse the relative contribution of the complex levee system from the impacts of the operation of Melvin Price lock and dam. The following method — though it only isolates and measures a portion of the ecosystem impacts — increases the comprehensiveness of the original Melvin Price analysis and presents a plausible path for USACE to include ecosystem service values in the analysis of the proposed NESP expansion in the UMR-IWW.

APPLYING THE FRAMEWORK VIA THE **MELVIN PRICE LOCK AND DAM EXPANSION**

The Melvin Price lock and dam expansion project was built to replace an existing structure, Lock and Dam No. 26 (LD26). Sited two miles downstream from LD26 at river mile 200.5, the dam at Melvin Price is 1,160 feet long, 42 feet tall, and retains 112,634 acre-feet of water. To apply the land-cover-change framework to Melvin Price, the first step is to determine the area impacted by the construction of the new lock and dam.

The analysis from 1974 used a land-cover change approach but limited its consideration to only the "unavoidable impacts" of the 600-acre pool that would be created by moving the structure two miles downstream from LD26 (USACE, 1974). The Planning and Guidance Notebook indicates that BCA should include an accounting of benefits (and costs) "wherever they accrue (even outside the study area) …" (USACE, 2000, pg. 2-10). The area studied in the initial analysis of Melvin Price in 1974 focused only on the new pool created between the two structures and did not account for any downstream or upstream land-cover changes. The largest possible area of impact would include the waterways and floodplains immediately above and below Melvin Price, extending to the next control structures along the river.

The next step in applying the land-cover change framework is to identify temporally relevant data. This analysis uses data from the USGS Upper Midwest Environmental Sciences Center, which provides geospatial data that describes land-cover classes in the UMR. To compare change over time, land-cover analysis must have data from both pre- and post-project. The latest available geospatial data in the period immediately prior to the construction of Melvin Price is from 1975. For the period after Melvin Price, data exist for a number of years including 1989, 1994, 2000, and 2011. This analysis opts to use data from 2011, as it is most likely to reflect a more complete state of land-cover change, since the construction of the second set of locks was not completed until 1994, and any subsequent land-cover changes could be expected to take some time to consolidate.

To perform a land-cover change analysis, data must also be spatially relevant. That is, data from the pre- and post-project years must represent the same area; for a variety of reasons, geospatial data does not always do this. Using land-cover data from 1975 and 2011, Earth Economics determined the spatial intersect — the area of overlap shared by the two years of data — and created the final area, 46,707 acres, for assessment of land-cover change, shown in Figure 4.

As illustrated by Figure 4, the area of analysis has expanded from 1974 to include changes upstream of Melvin Price, extending to the next structure on the Mississippi, Lock and Dam 25 — a stretch of water known as Pool 26. By comparing the data "footprints" of 1975 and 2011, 46,707 acres of historical land-cover data overlap was discovered. Although this is nearly 80 times larger than the 1974 area of study, it is still incomplete, as it omits the 56 miles of the Illinois Waterway (IWW) from its confluence with the main stem of the Mississippi River to the La Grange lock and dam. USACE now acknowledges that the IWW is part of Melvin Price's area of impact (USACE, 2004, pg. 36), and should be included in BCA. Additionally, downstream changes in land cover — though they do exist — could not be included due to a lack of data.

Once the area of analysis is established, the next step is to determine the land-cover types identified by the data. The quality of land-cover data generally improves over time, and newer data tend to identify a greater number of land-cover types. Performing comparisons between newer and older data makes it impossible to take advantage of the higher-quality data, which limits this analysis to those categories identified by the earliest period of study.[2] Consequently, this analysis focuses on changes in the following eight land-cover types: agricultural, developed, grasses, shallow water, deep water, sand and mud, herbaceous wetlands, and woody wetlands. The specific status of these land-cover classes in the pre- and post-Melvin Price years is displayed by Figure 6.

FIGURE 4 POOL 26 STUDY AREA

SOURCES: USGS, UPPER MIDWEST ENVIRONMENTAL CENTER

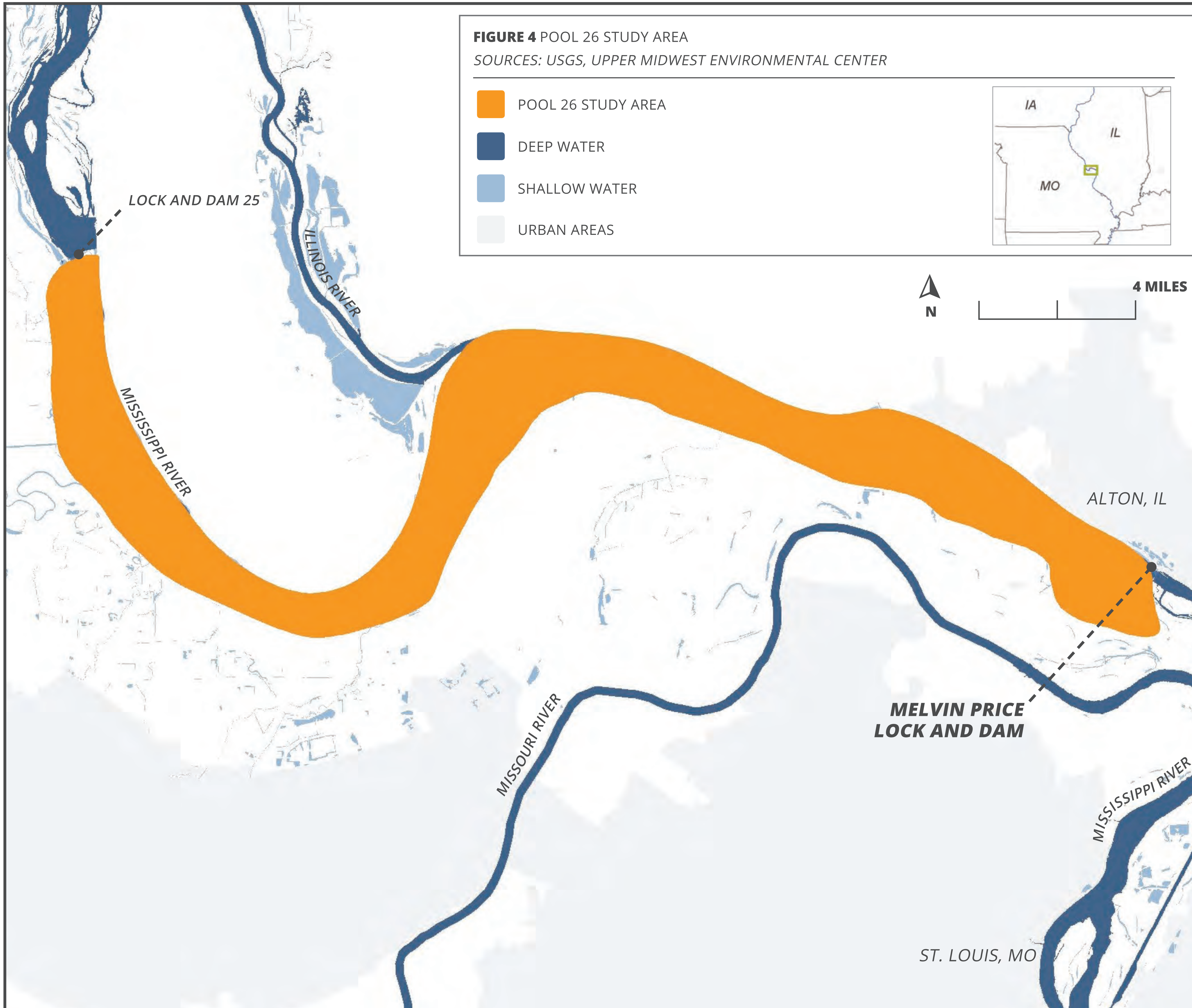


Table 5 summarizes net land-cover changes between 1975 and 2011 in the Pool 26 area of study. These net changes are the result of a single land cover type — woody wetlands, for example — being converted to other land cover types (i.e., loss of woody wetlands), and of the other land cover types being converted to woody wetlands (i.e., gain of woody wetlands).

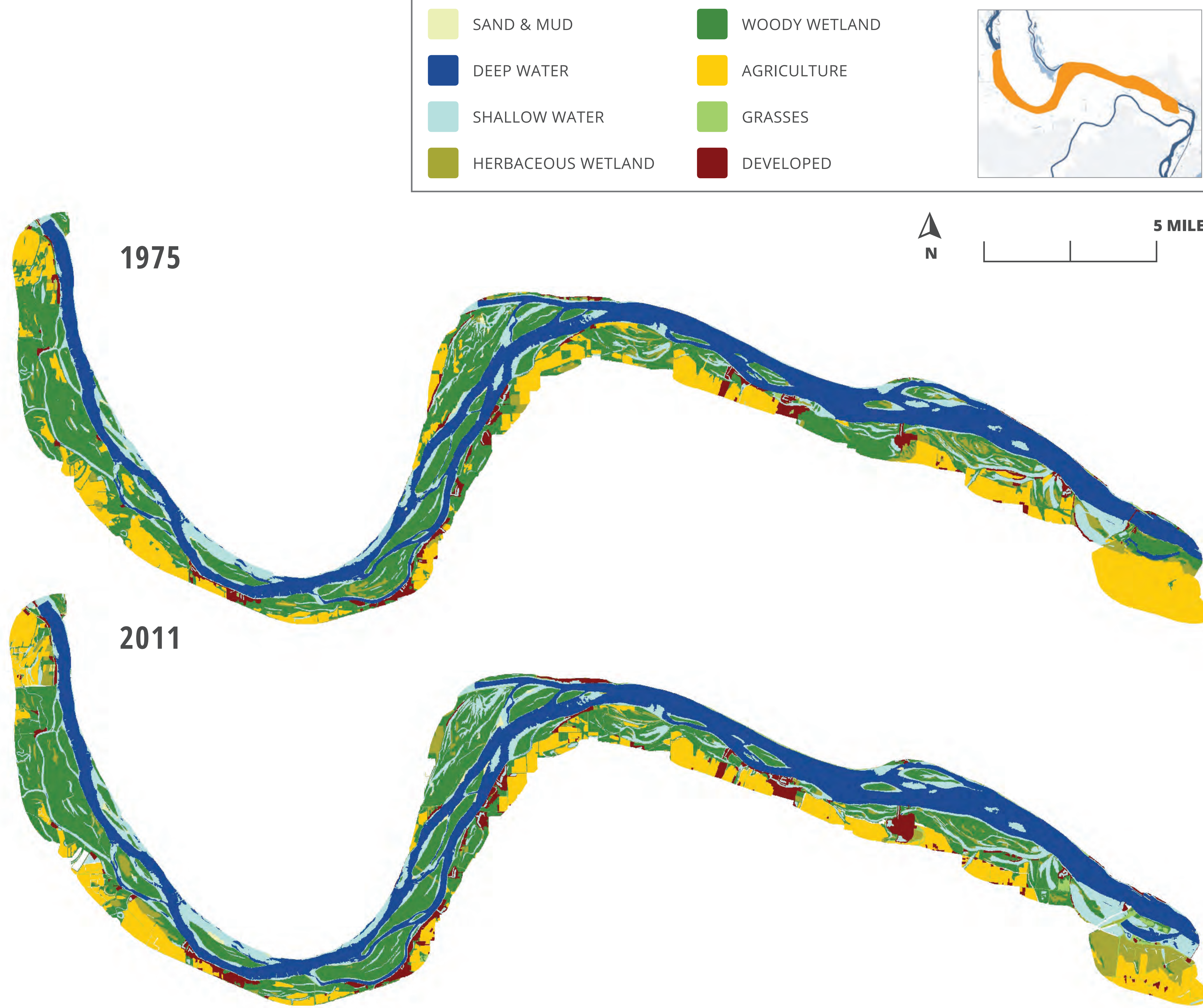
After identifying changes in land cover, the next step is to identify the value of the ecosystem services produced by the land-cover types present in the study area. This valuation is performed using a well-established methodology known as benefit transfer. Benefit transfer takes ecosystem service values from existing studies, compares the site of interest to the site valued in the study, and — should the two sites prove sufficiently similar — applies the value to the ecosystem in the area of interest (Rosenberger and Loomis, 2003). The process is very similar to property appraisals, where price is estimated based on properties with similar features and amenities.

FIGURE 5 LAND-COVER CHANGE OVER TIME IN POOL 26

LAND-COVER	1975 (ACRES)	NET (ACRES)	% INCREASE	2011 (ACRES)
SAND & MUD	141	74	52%	216
DEEP WATER	11,984	189	2%	12,172
SHALLOW WATER	6,140	842	14%	6,982
HERBACEOUS WETLAND	1,806	622	34%	2,429
WOODY WETLAND	14,825	-1,101	-7%	13,724
AGRICULTURE	10,198	-2,054	-20%	8,144
GRASSES	83	929	1118%	1,102
DEVELOPED	1,529	499	33%	2,028

FIGURE 6 POOL 26 LAND-COVER COMPARISON BETWEEN 1975 AND 2011

SOURCES: USGS, UPPER MIDWEST ENVIRONMENTAL CENTER



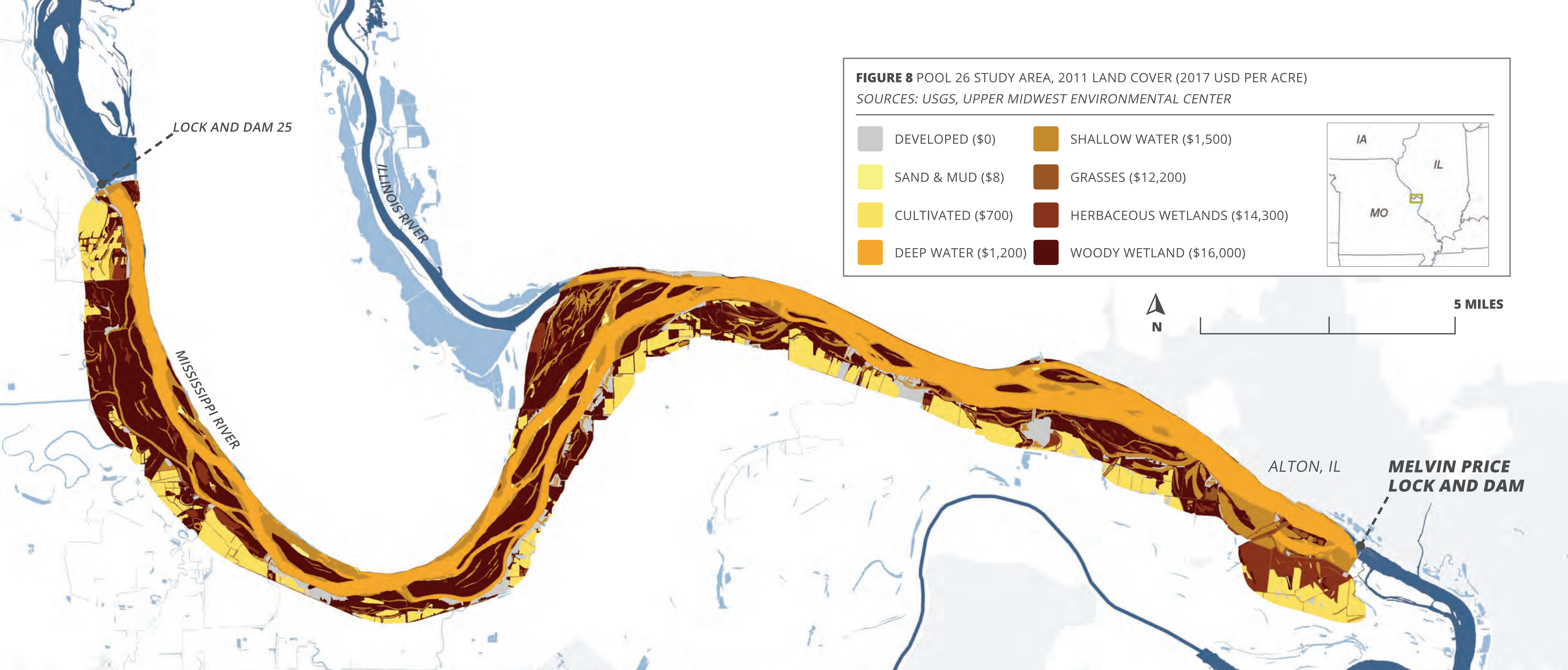


FIGURE 8 POOL 26 STUDY AREA, 2011 LAND COVER (2017 USD PER ACRE)
SOURCES: USGS, UPPER MIDWEST ENVIRONMENTAL CENTER

FIGURE 7 ECOSYSTEM GOODS & SERVICES BY LAND-COVER TYPE

ECOSYSTEM SERVICES BY LAND COVER TYPE	FOOD	ENERGY, RAW MATERIALS	WATER STORAGE	AIR QUALITY	BIOLOGICAL CONTROL	CLIMATE STABILITY	DISASTER RISK REDUCTION	POLLINATION, SEED DISPERSAL	SOIL FORMATION	SOIL RETENTION	WATER QUALITY	WATER CAPTURE, CONVEYANCE, SUPPLY	HABITAT	AESTHETIC INFORMATION	CULTURAL VALUE	RECREATION, TOURISM
Sand or Mud												●				
Deep Water	●										●	●		●	●	
Shallow Water	●										●	●	●	●	●	●
Herbaceous Wetlands		●				●	●			●	●		●		●	●
Woody Wetlands	●	●	●	●	●	●	●		●	●	●	●	●		●	●
Agriculture	●			●	●	●		●	●	●	●	●		●		●
Grasses		●			●	●		●	●	●	●	●	●	●		●

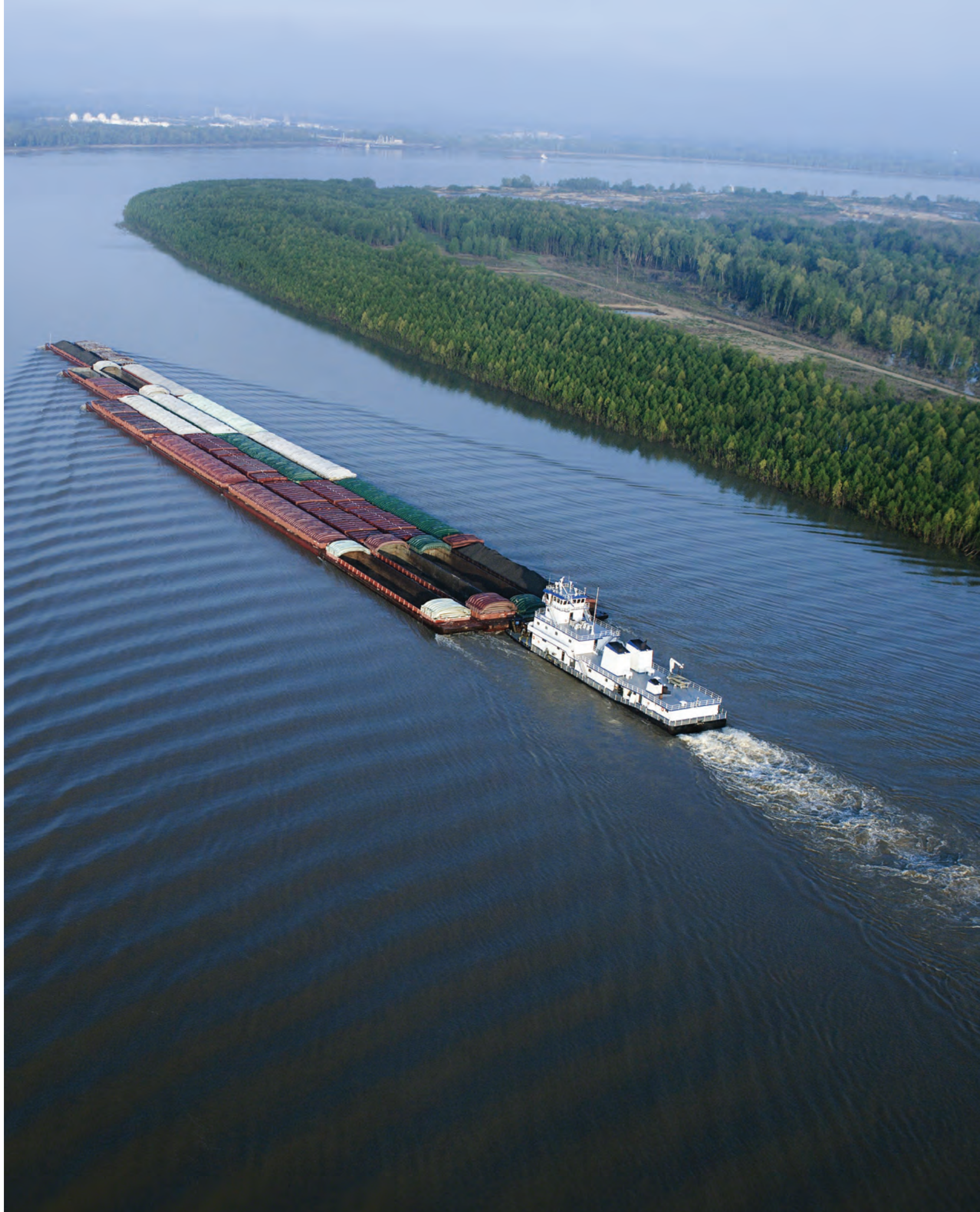
● = VALUE INCLUDED IN THIS ANALYSIS

The final step in being able to compare the relative benefits and costs of converting one land-cover type to another is to map the ecosystem service values onto the identified changes in land cover. To restate, a net gain or loss in one land-cover type is a result of conversions to and from multiple other types. Each land-cover class has a different per-acre value; therefore, measuring the total change in value is an aggregate that reflects multiple land-cover conversions (see Appendix A). Comparing the land-cover changes and associated ecosystem service values from 1975 and 2011 isolates the relevant value changes between the years, an example of which is shown in Figure 9.

Not all ecosystems produce the same services at the same levels, so different land-cover patterns produce different bundles of ecosystem services; consequently, there are different net contributions to human well-being. This also means that land-cover change usually results in tradeoffs, as one or more ecosystem functions and associated services is diminished or increased. To illustrate the point, woody wetlands have a large per-acre value (see Figure 8). Converting woody wetlands — an ecologically productive and valuable land-cover type — to the significantly less-valuable sand/mud land-cover type results in substantial losses of nearly $750,000 (see Appendix A). These losses are a function of both the number of acres converted from woody wetlands to sand/mud (very few), and of the per-acre value difference between the two land-cover types (very high).

FIGURE 9 ECOSYSTEM SERVICE VALUE CHANGE

SOURCES: USGS, UPPER MIDWEST ENVIRONMENTAL CENTER AND THE NATIONAL MAP



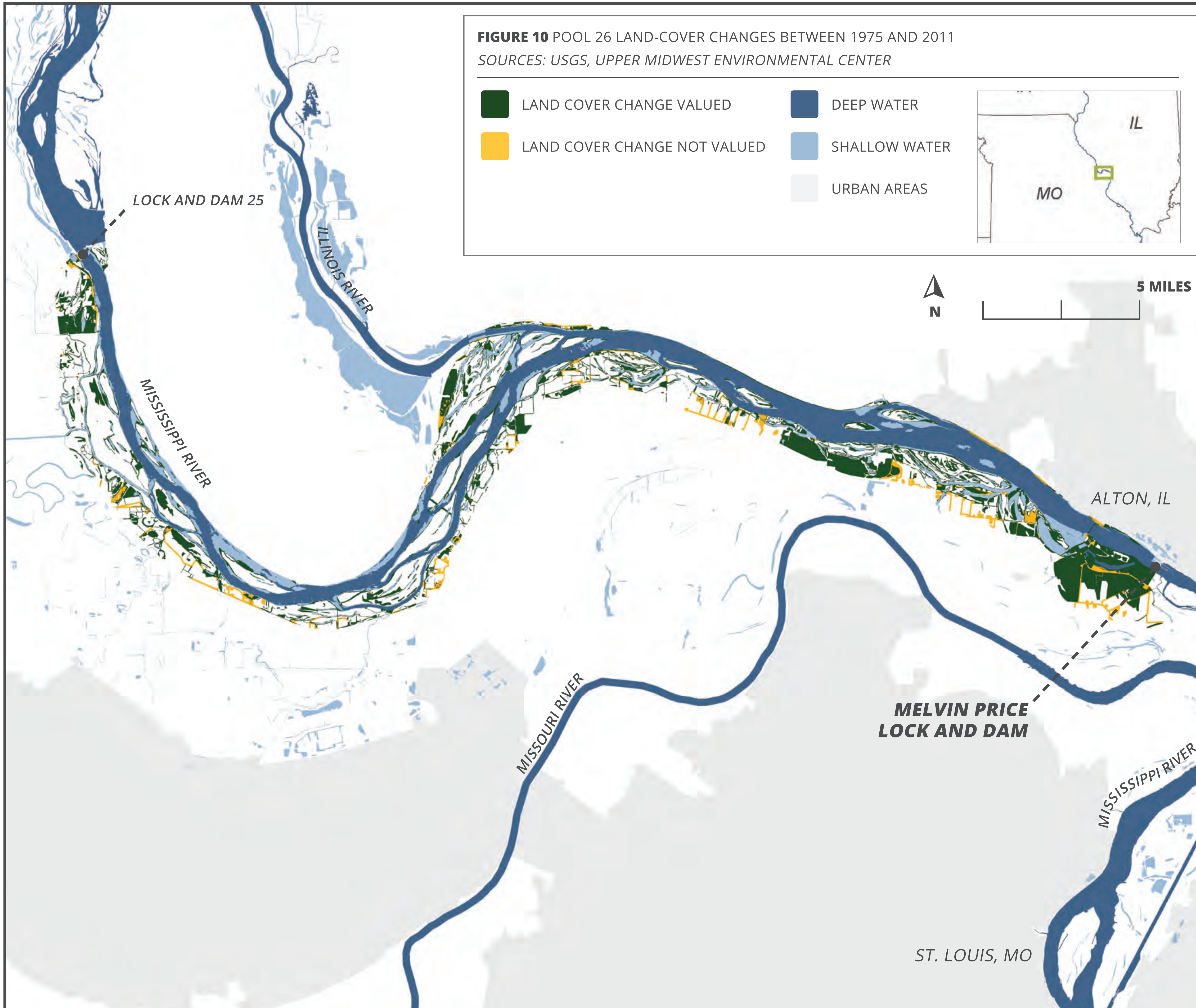
RESULTS

This analysis shows that of the 46,706 acres that comprise the study area, 10,294 acres were subject to land-cover conversion between 1975 and 2011 — over one-fifth of the study area. Of these changes, 926 acres were not valued because they represent land cover changes that cannot be plausibly attributed to the locks and dam (e.g., developed land to agriculture). This leaves 9,368 acres of land-cover changes to be valued. This area that is relevant to the valuation exercise is summarized in Figure 10.

The benefit transfer process is facilitated by Earth Economics' proprietary Ecosystem Valuation Toolkit (EVT), a repository of over 2,000 individual ecosystem service value estimates. These estimates are drawn from scholarly literature, government reports, and other grey literature and have been twice-reviewed by Earth Economics analysts to ensure the methodologies and data used to identify ecosystem values are appropriate and rigorous. EVT helps to construct appropriate comparisons between these studies and the area of interest by making it easy to select for attributes such as climate type, ecosystem, and location. Finally, EVT reports the ecosystem service values in dollars per acre, per year, which can then be applied to the area of interest by mapping them onto the changes in land cover. Querying EVT resulted in 39 studies with values that were appropriate for transfer to the example of Melvin Price.

FIGURE 10 POOL 26 LAND-COVER CHANGES BETWEEN 1975 AND 2011

SOURCES: USGS, UPPER MIDWEST ENVIRONMENTAL CENTER



The 9,368 acres of relevant land cover changes during this time period resulted in an annual net loss of more than $2.4 million (2017 USD) (see Appendix A). The sum of the values of the known net ecosystem goods and services attributable to Melvin Price operations is the difference between the land-cover snapshots of 1975 and 2011. The most significant losses in ecosystem services come from the loss of woody wetlands, often converted to shallow water ($17.3M per year) and agriculture ($15.6M per year). However, there were also gains from the conversion of agricultural lands to herbaceous and woody wetlands ($34.5M). Therefore, net losses for this comparison are conservatively estimated at $2.4 million — a function of the unique land-cover type conversions as well as different per-acre values for each land-cover type. Again, this figure represents a comparison of two "snapshots" in time — the value of ecosystem services provided by land cover in 2011, minus the ecosystem services provided in 1975.

Such "snapshot" comparisons are valuable, but they are not appropriate on their own for including in BCA. Estimating the cumulative impact — that is, the value that belongs in BCA — of Melvin Price requires time series analysis. The loss of ecosystem services, such as the conversion of one land-cover type to another, is something that produces cumulative and incremental impacts over time. For example, changes that reduce an ecosystem's capacity to process nitrogen will allow excess nutrients to load surface and groundwater, reducing water quality and placing additional cost burdens on treatment facilities. Ideally, estimates of the cumulative loss of ecosystem service would be based on geospatial data immediately prior to each stage of construction (e.g., the replacement for LD26, and the second expanded structure), as well as biophysical rates of conversion from one land-cover type to another (e.g., successional processes from herbaceous to woody wetlands). Though it is beyond the scope of this report to perform such year-by-year comparison, an alternative path to modeling cumulative impacts is to calculate average annual land-cover conversion rates.

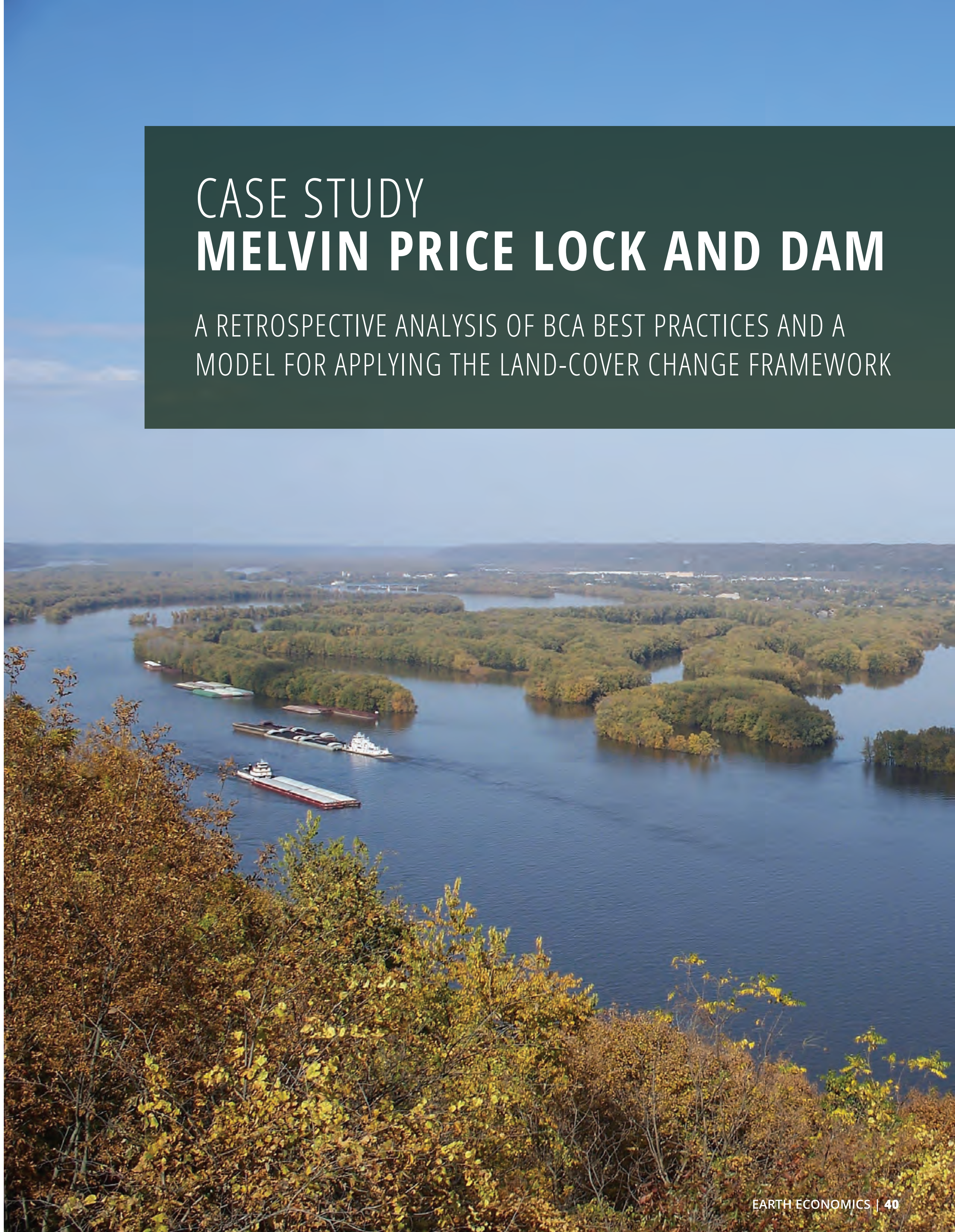
Prior to making the calculation, this analysis assumes that the land-cover distribution of 1975 remained the same until 1988, the year before Melvin Price was completed. To calculate the annual rates of land-cover conversion attributable to Melvin Price, the acres gained or lost between 1975 and 2011 of each land-cover class are divided by 23 (the number of years between 1989 and 2011). Then, the analysis begins in 1989, again assuming the state of land cover is equivalent to 1975. For each subsequent year, a linear rate of change is modeled by applying the average annual rate of conversion for each land-cover type to generate total acres of each type of land cover. These estimated annual land-cover changes are then converted to dollar values using the annual per-acre ecosystem service values from Figure 7.

This results in cumulative losses of $23[3] to $29[4] million (2017 USD) from 1989 through 2011 — a period of 23 years. These figures represent the core of the ecosystem service value losses that would populate a complete BCA. A complete BCA would need to extrapolate these costs over a 50-year period of analysis. Though performing this projection is beyond the scope of this report, USACE is well positioned to conduct linear or non-linear modeling of these ecosystem services in consultation with its scientists familiar with the hydrology of the UMR. It is assumed that any approach would reduce the annual ecosystem service losses by some factor (whether linear or non-linear) and within certain bounds (i.e., modeling a range of ecosystem degradation from, for example, 80 percent to 20 percent functionality, and not extending the model to include the extremes of 100 percent or 0 percent ecosystem functionality — perfect ecosystem health or total degradation). This assumption reflects the fact that if ecosystems experience annual degradation, they would provide correspondingly fewer ecosystem services with each year, reducing the value of the services they provide.

[3] Using the low values for ecosystem services identified by EVT
[4] Using the high values for ecosystem services identified by EVT

CASE STUDY
MELVIN PRICE LOCK AND DAM

A RETROSPECTIVE ANALYSIS OF BCA BEST PRACTICES AND A MODEL FOR APPLYING THE LAND-COVER CHANGE FRAMEWORK



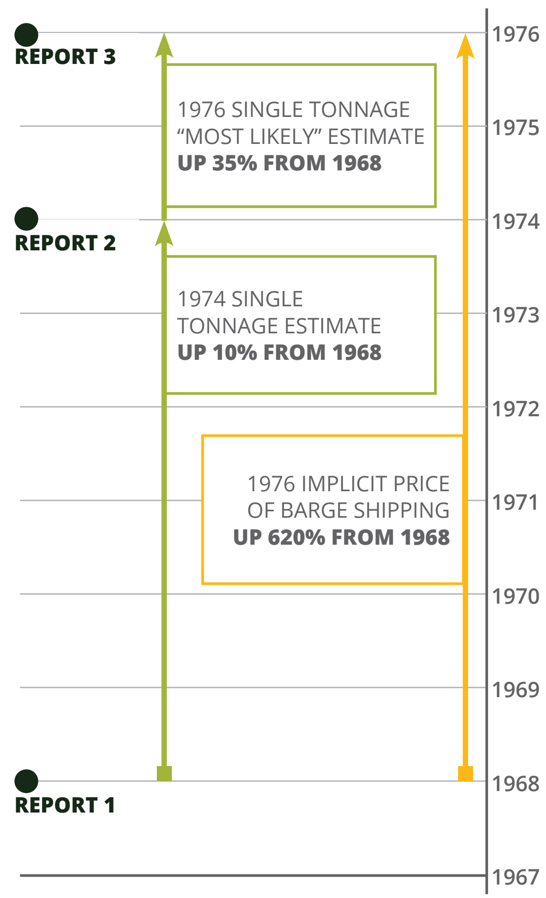
CASE STUDY

BENEFIT FORECASTING IN MELVIN PRICE

Forecasting benefits plays an important role in shaping the results of benefit-cost analysis. In the USACE analyses of the Melvin Price lock and dam expansion, commodity supply and demand forecasts, the associated traffic forecasts, and the savings rate (based on the cost of shipping via barge versus its alternatives) are the primary inputs for estimating benefits in dollars. See table, below, for the three separate analyses conducted by USACE that estimated shipping volumes and benefits.

The three reports produced a range of average annual tons of commodities shipped. The first two reports from 1968 and 1974 each produced a single tonnage estimate, and the 1974 estimate is about 10% greater than the 1968 estimate. The third report in 1976 produced three estimates—"high," "low," and "most likely," the latter of which was ultimately the value chosen for the BCA. The "high" estimate is extremely close to the "most likely" estimate and is not displayed in the table below. The "most likely" estimate represents roughly a 35% increase relative to the 1968 estimate; the "low," a 25% decrease.

The analyses also produced a range of average annual economic benefits, which—in its most simple form—is a calculation of quantity (the annual tonnage) multiplied by a price per ton. The shipping price is not provided by the reports and is calculated here. To calculate the implicit price of barge shipping, the average annual economic benefits is divided by the projected tonnage. Though the projected tonnage increased with each subsequent analysis (35% from 1968 to 1976), far greater increases are observed in the implicit price of barge shipping between the 1968 and the 1976 report—it spiked by 620%. It is unclear whether projected increases in fuel prices, in the prices of substitute shipping methods, or other factors prompted this increase, but it is clear that the price projection—rather than the tonnage projection—is the primary driver of the dramatically increased benefits calculated by the 1976 analysis.



Projected and Actual Shipping Volumes and Associated Economic Benefits, 1989-2011

USACE BCA	1968	1974	1976 ("MOST LIKELY")	1976 ("LOW")	ACTUAL
TONNAGE (AVERAGE ANNUAL)	92,060,000	101,049,000	123,434,000	69,898,000	69,470,000
IMPLICIT PRICE OF BARGE SHIPPING (CALCULATED)	$2	$2	$15	$1	DATA UNAVAILABLE
AVERAGE ANNUAL ECONOMIC BENEFITS (2016 USD)	$224,849,000	$243,100,000	$1,841,000,000	$100,600,000	DATA UNAVAILABLE

SENSITIVITY ANALYSIS

Sensitivity analysis can demonstrate to what degree the average annual economic benefits are driven by each of the variables that inform it. If slight adjustments in the shipping rate produce massive changes in the results, then shipping rate is a variable that carries significant weight. Identifying which variables wield the most influence over the final results is important so that the analyst can pay special attention to crafting the most accurate projections possible.

SCENARIO ANALYSIS

Projecting the future is a difficult and uncertain exercise. Sometimes even the most meticulously crafted assumptions for important variables can go awry. To mitigate this, another best practice is demonstrated by the 1976 report: scenario analysis. Simultaneously viewing three sets of results reflecting "low," "high," and "median" or "most likely" scenarios based on different suites of assumptions draws attention to the uncertainties inherent in forecasting and opens a path towards expanded decision criteria. For example, a plan with the narrowest range of outcomes (i.e., more certainty) might be chosen over a plan with a wider range between its "high" and "low" scenarios, even if the "high" would produce the greatest overall net benefits.

Regularly revisiting old BCA and replacing projections with actual benefits *(e.g., replacing projected tons shipped with actual tons shipped, and projected prices with actual prices)* **can reveal gaps or patterns in forecasting practices, so that lessons can be learned and applied to improve future analyses.**


Source: USGS

CASE STUDY

COST FORECASTING
IN MELVIN PRICE

Cost overruns are common in large infrastructure projects. Cost forecasts in the USACE reports from the time of Melvin Price are separated into two categories of cost. The first category is called federal first costs. These are the upfront costs associated with a project — the cost of buying land and purchasing the materials and labor necessary for construction, supervision and administration costs, relocation costs, design costs, et al. Three separate analyses conducted by USACE estimated these federal first costs:

Estimated First Costs vs. Total Appropriations (billions, inflated to 2016 USD)

YEAR ESTIMATED	1968	1974	1975	ACTUAL APPROPRIATIONS, 1980-2012[1]
COSTS	$1.38	$2.05	$2.04	$2.18

Sources: USACE, 1968, pg. 31-32; USACE, 1974, pg. 11-12; USACE, 1975, pg. 9-8; Annual USACE Chief Reports

While the estimates from 1974 and 1975 are similar, they are noticeably different from the 1968 estimate. The 1968 report provided the initial cost-benefit ratio that secured congressional approval — the analysis is the first look at costs and benefits in the planning process. The federal first costs of 1968 are based on initial feasibility studies and rough estimates of engineering and design costs. Once approved, the project needed to develop engineering and design specifics in greater detail. The 1974 report transformed the project from an initial concept to one with specific design specifications; incorporating highly specific rather than broad-brush cost estimates resulted in projected costs increasing by 49 percent between 1968 and 1974.

Even after including more specific cost estimates, the 1974 and 1975 reports still underestimate the true cost. By comparing the appropriations from the USACE Annual Chief Reports to the highest cost estimate from 1974, it is clear that the Melvin Price project has experienced, at minimum, a six percent cost overrun (see footnote 1).

The second category of costs in the USACE reports is annual costs. These costs extend over the life of the project, and they tend to be less obvious than, for instance, the materials and labor that compose a large portion of the federal first costs. One major component of annual costs is strongly correlated with federal first costs: annual interest payments. To pay for a large infrastructure project with high upfront costs, the government must borrow — and pay back — that initial investment. In the 1968 report, interest payments represent a full 77 percent of the total estimated annual costs. Because of this relationship, as federal first costs increase, annual costs also tend to increase. Other inputs that affect annual cost estimates include ongoing operations, depreciation, and minor maintenance; major rehabilitation costs are budgeted separately. Three separate analyses conducted by USACE estimated these annual costs:

Estimated Annual Costs (millions, inflated to 2016 USD)

YEAR ESTIMATED	1968	1974	1975
COSTS	66.2	153.4	211.3

Sources: USACE, 1968, pg. 31-32; USACE, 1974, pg. 11-12; USACE, 1975, pg. 9-8; Annual USACE Chief Reports

The increase in annual costs from 1968 to 1974 is immediately apparent. This large increase corresponds with the increased federal first costs between 1968 and 1974. As federal first costs went up, so too did annual costs; increased interest payments were a likely driver of this. However, federal first cost estimates stayed roughly the same in the 1974 and 1975 reports, even as annual costs increased again. It follows that this increase in annual costs was not driven by increased annual interest payments, but by one of the other cost factors (e.g., operations and maintenance) that was revised upward in the 1975 report.

Congress makes appropriation decisions based on the results of initial feasibility studies. These studies outline the general shape of a project to determine if their estimated benefits merit the investment of scarce government resources. They are necessarily sparse on detail, because it would likely not be cost-effective to dedicate the resources necessary to conduct feasibility studies with such specificity that they could be used for both initial approval and construction. Federal first costs tend to go up as the project adds design-specific engineering costs. Holding other costs and benefits equal, this cost increase will reduce the benefit-cost ratio (BCR) of the project. Sometimes a project might look like a slam-dunk investment at first, but on closer inspection it might appear like less of a sure thing, especially when compared against the other proposed projects being initially considered. This underscores the importance of considering a broad range of project options starting from the beginning of a project, and of following a set of best practices when forecasting project costs.

[1] Costs could only be identified for the 33-year period between 1980 and 2012, and they are sourced from the annual USACE Chief Reports from the corresponding years. Costs only reflect "new work" as reported in the USACE Annual Chief Reports. This figure excludes costs categories including "operations and care," "maintenance," and "dredging." These are considered annual costs, rather than federal first costs. No cost data were identified for 1989 or 1996, and because some additional new work can be expected for the remaining 17 years of the typical 50-year period of economic analysis, this estimate represents a low bound.

ONE OPTION FOR ADDRESSING THESE CHALLENGES IN COST FORECASTING:

A conservative approach for cost forecasting would be to make the process more adaptive. Adopting an adaptive approach would allow USACE to respond to new flows of information as the planning process advances and adjust its decisions as new evidence dictates. This would help to address the cost overruns that are so common in construction projects and prevent getting locked into a single option that becomes unexpectedly costly as plans gain specificity. Should emerging costs move a project's BCR below a certain threshold, USACE could be prepared to pursue other project alternatives. A best practice would be to revisit the second- and third-best project alternatives once the preferred plan has updated cost projections and determine if the plan is still preferred, or if it makes sense to explore the alternatives in greater detail. Having the flexibility to reassess projects as new information emerges — rather than being locked into a single option — would help ensure that investment decisions represent the most efficient use of taxpayer dollars.

CASE STUDY

CHOOSING BETWEEN **PROJECT ALTERNATIVES**

The 1975 USACE report listed the benefit-cost ratios associated with different alternatives for addressing the problem of vessel delays on Locks and Dam No. 26:

PROJECT ALTERNATIVE	PROJECTED CAPACITY (TONS)	BCA
NO ACTION WITH CAPACITY IMPROVEMENTS	73,000,000	9.9
REHABILITATION WITH CAPACITY IMPROVEMENTS	73,000,000	0.18
NEW DAM, SINGLE 1200-FOOT LOCK	86,000,000	3.9
REHABILITATION, ADD 1200-FOOT LOCK	127,000,000	9.3
NEW DAM, 1200-FOOT AND 600-FOOT LOCK	142,000,000	8.8
NEW DAM, TWO 1200-FOOT LOCKS	175,000,000	8.6

Source: USACE, 1975, pg. S-8.

Ultimately, a new dam plus one 600-foot lock and one 1,200-foot lock — now known as Melvin Price — was chosen to replace Locks and Dam No. 26. Looking at this table, a question arises: Did the Corps arrive at the decision to pursue Melvin Price by focusing on BCR, on projected capacity, or on some other factor or factors? If the evaluation was more holistic, how were the different factors weighted in selecting the best option?

Clearly, an evaluation that focused exclusively on benefit-cost ratio would not have favored Melvin Price. According to BCR, two options would have been preferred: adding capacity improvements to Lock and Dam No. 26 and leaving the structures alone (BCR of 9.9), or leaving Lock and Dam No. 26 in place, rehabilitating it, and building a new 1,200-foot lock to complement the smaller, existing one (BCR of 9.3).

BCR is a measure of efficiency, or the amount of benefit per dollar of cost. While our analysis did not find existing documentation that clearly explains the decision to pursue Melvin Price over other alternatives, there are plausible reasons for rejecting the more efficient options. Perhaps the Corps chose to prioritize capacity improvements, based on the projected benefits associated with the aggressive vessel traffic increase projections from the 1975 report. This would have led the Corps to pass on the rehabilitation and new lock option in favor of the next-highest BCR.

The greatest BCR belongs to the no-action solution: 9.9. Perhaps prioritizing projects with larger projected capacities played a role in dismissing this option. However, language scattered throughout the reports of the time seems to point to concern for the structural integrity of the existing dam. It seems that the overriding concerns of USACE ruled out the most-efficient option, likely due to small but potentially catastrophic risks. The imperative to improve the structural integrity of the dam would have led USACE to rule out the more-efficient no-action alternative. Ultimately, this is speculative — many complicating and conflating factors enter into the decision-making process. Without clear decision support methods that are accessible to the public, the rationale for not pursuing the no-action solution in 1975 is unknowable.

Any number factors could have influenced the ultimate decision to select Melvin Price. One likely candidate that merits discussion is the magnitude of the project. USACE guidance has historically framed project justification criteria in terms of maximizing NED benefits rather than maximizing efficiency. In practice, this means that once a project is determined to have a positive return on the investment of taxpayer dollars over a certain threshold (for instance, any project above a 1.5 BCR), the one with the greatest NED benefit will win out. To illustrate how magnitude can influence decisions, consider two alternatives:

PROJECT COSTS	BENEFITS	BCR
$1,000	$100,000	100.0
$500,000	$1,000,000	2.0

While one of the two hypothetical projects in the table above provides a much greater rate of return, USACE guidelines would suggest that the other option is the most desirable. Since both return a BCR greater than 1.5, the project with the greatest net benefits is selected.

BEST PRACTICES FOR CHOOSING BETWEEN PROJECT ALTERNATIVES:

- While explanations for choosing Melvin Price over the other options may exist piecemeal within larger documents from the time, this analysis was unable to locate them. A white paper or an executive summary attached to the final BCA that explains the decision rationale in a clear and concise manner could be a helpful tool in explaining investment choices to stakeholders outside of USACE.
- It is clear that the decision to pursue Melvin Price was not motivated by a single factor alone; holistic evaluation of project alternatives is a best practice. Recent USACE guidance has been pursuing just that by attempting to expand beyond its NED-centric evaluative tradition to systematically incorporate the findings of the RED, EQ, and OSE accounts in its decisions.
- USACE could consider pursuing small-scale projects with high BCRs, even though this would likely come with some administrative overhead. Even when the benefits of a project are not large, they may still significantly outweigh the costs of implementing the project. Some highly efficient investments that are not considered due to the present focus on maximizing NED benefits may actually be worth pursuing.
- Given the uncertainty inherent in forecasting future costs and benefits, weighting efficiency more heavily in the holistic evaluation of project options could be a conservative approach to selecting project alternatives. Selecting projects with the highest estimated rate of return over options with lower BCRs but greater net benefits could increase the likelihood that a positive BCR will ultimately materialize, which would lead to better outcomes.

CASE STUDY

ACCOUNTING FOR **ECOSYSTEM SERVICES**

When the initial benefit-cost analyses of Melvin Price were conducted, the value of ecosystems was not widely recognized or incorporated into planning decisions. Today, that has changed. Both federal guidelines and the USACE are seeking to modernize BCA to include ecosystem services, and advancements in valuation techniques allow modern BCA to systematically account for the changes in costs and benefits associated with a fluctuating stock of natural capital (USACE, 2005; CEQ, 2013).

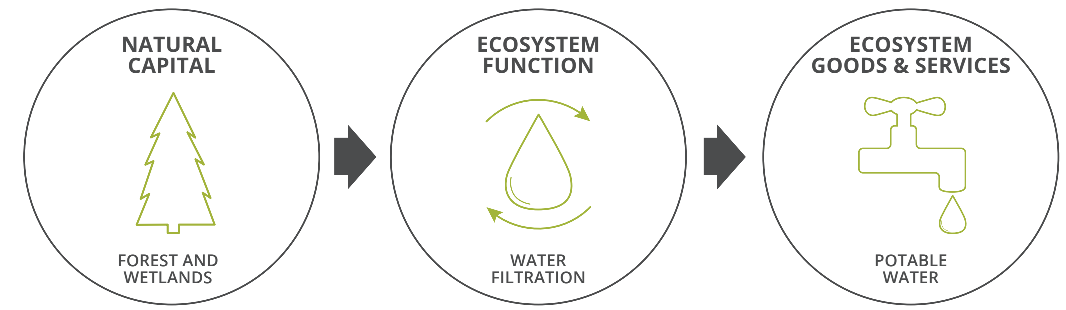
The original analyses of Melvin Price estimated the flow of costs and benefits attributable to the project and assembled them into benefit-cost ratios. Without accounting for the beneficial goods and services provided for free by nature, a critical cost driver is missing from the original analyses.

BEST PRACTICES:

- In keeping with the recognition of the contributions of nature to human and economic wellbeing, account for ecosystem service values in dollars whenever possible. Doing so will help expand the suite of values that influence investment decisions, providing additional information that is valuable to decision makers. Measuring ecosystem services in dollars allows them to be included in the NED account — still the primary driver of USACE investment decisions — rather than be pushed to the EQ account where environmental impacts are discussed in qualitative or biophysical terms.
- The land-cover change framework presented in this report is one useful method for valuing ecosystem services. By adopting this framework, USACE would create a standardized approach for measuring ecosystem service values where none currently exists, thereby helping the agency comply with the broader trend at the federal level and USACE's own stated desire to systematically include ecosystem service values in decision-making.

CAPITAL FUNCTIONS

The graphic below illustrates the relationship among natural capital, ecosystem function, and the ecosystem goods and services that people receive from nature.



FROM

1989-2011,

ECOSYSTEM SERVICE LOSSES

ATTRIBUTABLE TO MELVIN PRICE WERE CONSERVATIVELY ESTIMATED BY THE LAND-COVER CHANGE ANALYSIS IN THIS REPORT TO BE BETWEEN

$23 MILLION AND $29 MILLION

(2016 USD).

While these costs may seem small relative to the other costs, on an annual basis they add roughly 10 percent to the costs of current operations and maintenance at Melvin Price.

DISCUSSION

It is only by accounting for the value of natural assets in BCA that USACE can be sure that investment decisions are made using the most complete information possible. This report presents the case for including environmental impacts in BCA as a standard best practice. This report also demonstrates the land-cover change framework for valuing those impacts through the example of Melvin Price with the intention of drawing out lessons and recommendations that can inform future planning decisions on the UMR.

It is only by accounting for the value of natural assets in BCA that USACE can be sure that investment decisions are made using the most complete information possible. This report presents the case for including environmental impacts in BCA as a standard best practice. This report also demonstrates the land-cover change framework for valuing those impacts through the example of Melvin Price with the intention of drawing out lessons and recommendations that can inform future planning decisions on the UMR.

The proposed NESP lock system expansion represents a clear opportunity for USACE to incorporate ecosystem service values into its decision-making. NESP is tasked with implementing navigation improvements to reduce vessel traffic delays while also "... restoring, protecting, and enhancing the environment" (USACE, n.d.). The UMR-IWW System Navigation Feasibility Study examined the state of 37 locks (29 on UMR and 8 on IWW), and recommended a suite of upgrades including new lock construction, lock expansion projects similar to that of Melvin Price, and other structural and non-structural interventions (USACE, 2004). This recommended plan was reexamined in 2008, and the resulting benefit-cost ratios for the proposed navigation improvements in the UMR-IWW fell between 0.2 to 1.3, based on low- and high-traffic scenarios (USACE, 2008). These BCA results do not appear to make a strong case for the proposed projects — even without considering the impact of additional construction on the provision of ecosystem services. Including ecosystem service values in BCA for future navigation projects on the UMR offers a monumental opportunity to arrive at win-win solutions that prioritize both the health and productivity of the river and the future prosperity of the nation.

Existing guidance at USACE makes plain the intent to include ecosystem services in planning decisions, while also outlining the challenges in doing so. It is hoped that this report can contribute to the existing literature of white papers, engineering circulars, and more formal guidance attempting to reconcile competing directives by introducing one clear method of systematizing the inclusion of ecosystem service in the NED account, in BCA, and ultimately in decision-making. The land-cover-change framework is useful amidst vague or competing regulatory guidance because — despite its technical structure — it is straightforward to integrate with existing BCA processes. It is easy to integrate, because ecosystem service values simply represent another category of costs or benefits that can be added to existing costs and benefits in the NED account and weighed by BCA. Additionally, valuing ecosystem services using the framework is very much in keeping with the Principles and Guidelines of 1983, which directs USACE to value ecosystem changes in dollars whenever possible so that they can be included in the NED account.

As emerging guidance seeks to help USACE adopt a more holistic and systematic analysis based on all four accounts that expands beyond the NED-centric tradition, the land-cover change framework can serve as an important intermediate step that will help broaden the range of information included in the NED account and in the investment decisions it informs. It is hoped that future BCA — such as for the proposed NESP expansion — will be developed with an eye toward a comprehensive accounting of costs and benefits that includes ecosystem service values, an abiding awareness of the uncertainty generated by each decision in the process, and a desire to incorporate the ever-evolving standards and best practices of the discipline of benefit-cost analysis.

APPENDICES

APPENDIX A SNAPSHOT COMPARISON (1975 AND 2011), CHANGE IN ECOSYSTEM SERVICE VALUES

FIGURE 11 NET ECOSYSTEM SERVICE VALUE CHANGE FROM LAND-COVER CONVERSION ATTRIBUTABLE TO MELVIN PRICE (2017 USD)

CHANGE TO: / CHANGE FROM:	SAND OR MUD	DEEP WATER	SHALLOW WATER	HERBACEOUS WETLANDS	WOODY WETLANDS	AGRICULTURE	GRASSES	DEVELOPED
SAND OR MUD	Ø	$10,872	$102,381	$57,239	$750,527	$681	$36,666	($8)
DEEP WATER	($36,239)	Ø	$0	$13,102	$29,521	$0	$22,028	($3,646)
SHALLOW WATER	($147,721)	$0	Ø	$1,631,577	$8,268,464	($7,818)	$1,162,023	($158,771)
HERBACEOUS WETLANDS	($85,858)	($144,118)	($4,162,447)	Ø	$1,363,712	($3,843,348)	($150,307)	($1,689,425)
WOODY WETLANDS	($830,370)	($1,583,119)	($17,334,762)	($710,059)	Ø	($15,608,958)	($1,146,462)	($5,575,686)
AGRICULTURE	($11,573)	$5,272	$134,476	$22,678,481	$11,893,996	Ø	Ø	Ø
GRASSES	($24,444)	($22,028)	($86,076)	$8,250	$37,466	Ø	Ø	Ø
DEVELOPED	$8	$23,094	$141,130	$429,515	$3,147,307	Ø	Ø	Ø
							NET CHANGE	($2,415,360)

APPENDIX B
ECOSYSTEM SERVICES, BY DEFINITION

ECOSYSTEM
SERVICES
BY DEFINITION

PROVISIONING	
Food	Can include crops, fish, game, and/or produce
Medicinal Resources	Can include traditional medicines, pharmaceuticals, and/or assay organisms
Ornamental Resources	Resources for clothing, jewerly, handicrafts, worship, and decoration
Energy and Raw Materials	Can include fuel, fiber, fertilizer, minerals, and/or energy
Water Storage	Amount of surface or ground water held and its capacity to reliably supply water
REGULATING	
Air Quality	Ability to create and maintain clean, breatable air
Biological Control	Pest and/or disease control
Climate Stability	Ability to support a stable climate at global or local levels
Disaster Risk Reduction	Ability to prevent and mitigate natural disasters, including flood, fire, drought, etc.
Genetic Transfer	Includes pollination and/or seed dispersal
Soil Formation	Soil creation for agricultural and/or ecosystem(s) integrity
Soil Quality	Soil quality improvement due to decomposition and pollutant removal
Soil Retention	Ability to retain arable land, slope stability, and coastal integrity
Water Quality	Water quality improvement due to decomposition and pollutant removal
Water Supply	Ability to provide natural irrigation, drainage, supply, flow, and use of water
Navigation	Ability to maintain neccersary water depth for recreational and commercial vessels
SUPPORTING	
Habitat and Nursery	Ability to maintain genetic and biological diversity, and to promote species growth
INFORMATION	
Aesthetic Information	Enjoyment and appreciation of nature through the senses (sight, sound, etc.)
Cultural Value	Use of nature in art, symbols, architecture, and religious/spiritual purposes
Recreation and Tourism	Can include hiking, boating, travel, camping, and more
Science and Education	Use of natural systems for education and scientific research

APPENDIX C
REFERENCES

Alexander, J.S., Wilson, R.C., & Green, W.R., 2012. A Brief History and Summary of the Effects of River Engineering and Dams on the Mississippi River System and Delta: U.S. Geological Survey Circular 1375. URL https://pubs.usgs.gov/circ/1375/C1375.pdf (accessed 2.12.19).

American Society of Civil Engineers (ASCE), 2017. Infrastructure Report Card. URL https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Inland-Waterways-Final.pdf (accessed 2.6.19).

American Society of Civil Engineers (ASCE), 2018. ASCE Federal Project BCR and Scoring Information Paper. URL https://www.asce.org/uploadedFiles/News_Articles/asce-bcr-paper-2018.pdf (accessed 2.6.19).

Belby, C.S., Rivera Pérez, C., & Gerrish, G.A., 2015. Understanding Ecosystem Change in Upper Mississippi River Backwaters through Geochemical and Biological Analyses of Sediment Cores. River Systems, 21(2-3), 163-181. https://doi.org/10.1127/rs/2015/0102

Blum, M.D. & Roberts, H.H., 2009. Drowning of the Mississippi Delta due to Insufficient Sediment Supply and Global Sea-Level Rise. Nature Geoscience, 2(7), 488-491. https://doi.org/10.1038/ngeo553

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L., 2017. Cost-benefit analysis: concepts and practice. Cambridge University Press.

Bushnell, W. & Knight, K., 2011. Regional Economic Development (RED) Procedures Handbook. U.S. Army Corps of Engineers Institute for Water Resources IWR Report 2011-RPT-01. URL https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2011-RPT-01.pdf

Carter, N.T. & Nesbitt, A.C., 2016. Discount Rates in the Economic Evaluation of U.S. Army Corps of Engineers Projects, CRS Rep. No. R44594. Congressional Research Service. URL https://crsreports.congress.gov/product/pdf/R/R44594 (accessed 2.11.19).

Carter, N.T., 2018. Army Corps of Engineers: Water Resource Authorization and Project Delivery Processes, CRS Rep. No. R45185. Congressional Research Service. URL https://fas.org/sgp/crs/natsec/R45185.pdf (accessed 2.6.19).

Carver, E. & Caudill, J., 2013. Banking on Nature: The Economic Benefits to Local Communities of National Wildlife Refuge Visitation. U.S. Fish and Wildlife Service, Division of Economics. URL https://digitalmedia.fws.gov/digital/collection/document/id/1832/ (accessed 2.12.19).

Council on Environmental Quality (CEQ), 2013. Updated Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies. URL https://obamawhitehouse.archives.gov/sites/default/files/final_principles_and_requirements_march_2013.pdf (accessed 2.7.19).

Dahl, T.E. & Allord, G.J., 1996. History of Wetlands in the Conterminous United States, in: Fretwell, J.D., Williams, J.S., & Redman, P.J. (Eds.), National Water Summary on Wetland Resources. United States Geological Survey Water Supply Paper 2425, Washington D.C., pg. 19-26. https://doi.org/10.3133/wsp2425

de Groot, R.S., Wilson, M.A., & Boumans, R.M.J., 2002. A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. Ecological Economics 41, 393–408. https://doi.org/10.1016/S0921-8009(02)00089-7

Donovan, S., Goldfuss, C., & Holdren, J., 2015. Incorporating Ecosystem Services into Federal Decision Making, M-16-01 [Memorandum]. Executive Office of the President of the United States, Washington D.C. Retrieved on 2.25.19 from https://obamawhitehouse.archives.gov/omb/memoranda_2016

Dorfman, R., 1978. Forty Years of Cost-Benefit Analysis, in: Stone, R., Peterson, W. (Eds.), Econometric Contributions to Public Policy: Proceedings of a Conference Held by the International Economic Association at Urbino, Italy, International Economic Association Series. Palgrave Macmillan UK, London, pg. 268–288. https://doi.org/10.1007/978-1-349-16003-7_13

Dunning, M., & Durden, S.E., 2009. Handbook on Applying "Other Social Effects" Factors in Corps of Engineers Water Resources Planning, IWR Report 09-R-4. URL https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/09-R-4.pdf (accessed 3.7.19).

Durden, S.E. & Fredericks, J., 2009. Economics Primer. U.S. Army Corps of Engineers Institute for Water Resources, IWR Report 09-R-3. URL https://www.iwr.usace.army.mil/portals/70/docs/iwrreports/iwrreport_09-r-3.pdf (accessed 2.6.19).

Durden, S.E. & Wegner-Johnson, M., 2013. Other Social Effects: A Primer. U.S. Army Corps of Engineers Institute for Water Resources, IWR Report 2013-R-02. URL https://www.iwr.usace.army.mil/portals/70/docs/iwrreports/2013-r-02.pdf

Federal Emergency Management Agency (FEMA), 2013. Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs, FEMA Mitigation Policy FP-108-024-01. URL https://www.fema.gov/media-library-data/20130726-1920-25045-4319/environmental_benefits_policy_june_18_2013_mitigation_policy_fp_108_024_01.pdf

Federal Emergency Management Agency (FEMA), 2018. Benefit-Cost Analysis [WWW Document]. URL https://www.fema.gov/benefit-cost-analysis (accessed 2.6.19).

Government Accountability Office (GAO), 2010. Army Corps of Engineers Budget Formulation Process Emphasizes Agency Priorities, but Transparency of Budget Presentation Could Be Improved. Report to the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives. GAO-10-453. URL https://www.gao.gov/assets/310/302800.pdf (accessed 3.18.19).

Guyon, L., Deutsch, C., Lundh, J., & Urich, R, 2012. Upper Mississippi River Systematic Forest Stewardship Plan. U.S. Army Corps of Engineers (USACE). URL https://www.mvd.usace.army.mil/Portals/52/docs/regional_flood_risk_management/our_mississippi/UMRSystemicFSP7-26-12.pdf (accessed 2.11.19).

House of Representatives Report 113-486, 2015. Energy and Water Development Appropriations Bill, Section 902 Authorization Limits. URL https://www.congress.gov/congressional-report/113th-congress/house-report/486 (accessed 12.7.19).

Housing and Urban Development (HUD), 2015. National Disaster Resilience Competition (NDRC), Benefit Cost Analysis: Appendix H. [WWW Document] URL https://www.hudexchange.info/course-content/ndrc-nofa-specific-benefit-cost-analysis-appendix-h-overview/NDRC-BCA-Appendix-H-overview-Webinar-Slides.pdf (accessed 3.4.19).

Industrial Agriculture: The Outdated, Unsustainable System that Dominates U.S. Food Production. [WWW Document], n.d. Union of Concerned Scientists. URL https://www.ucsusa.org/our-work/food-agriculture/our-failing-food-system/industrial-agriculture (accessed 2.13.19).

Johnson, B.L. and Hagerty, K.H., editors, 2008. Status and Trends of Selected Resources of the Upper Mississippi River System. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. Technical Report LTRMP 2008-T002. URL https://pubs.usgs.gov/mis/LTRMP2008-T002/pdf/LTRMP2008-T002_web.pdf (accessed 2.13.19).

Knight, K., 2008. Issues and Applications in Formulation and Evaluation Considering the 4 P & G Accounts. IWR White Paper. URL https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/WhitePaper4Accounts.pdf (accessed 2.11.19).

National Parks Service, 2018. Mississippi River Facts [WWW document]. URL https://www.nps.gov/miss/riverfacts.htm (accessed 2.12.19).

National Parks Service, n.d. Asian Carp Overview [WWW document]. URL https://www.nps.gov/miss/learn/nature/ascarpover.htm?dom=pscau&src=syn (accessed 2.12.19).

National Research Council, 2004. Analytical Methods and Approaches for Water Resources Project Planning. The National Academies Press, Washington, D.C. https://doi.org/10.17226/10973.

National Research Council, 2005. Science and Planning on the Upper Mississippi River and Illinois Waterway—Highlights of the National Academies Reports on Managing the Nation's Largest Lock and Dam System. National Academy of Sciences. URL https://www.nap.edu/resource/11444/upper_mississippi_final.pdf (accessed 2.14.19).

O'Brien, W.P., Rathbun, M.Y., & O'Bannon, P., 1992. Early Navigation on the Upper Mississippi River, in: Whiteacre, C. (ed.), Gateways to Commerce: The U.S. Army Corps of Engineers' 9-Foot Channel Project on the Upper Mississippi River. National Park Service, Rocky Mountain Region No. 2. Accessed on 2.25.19 at https://www.nps.gov/parkhistory/online_books/rmr/2/index.htm

Office of Management and Budget (OMB), n.d. OMB Circular A-94 Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. URL https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf (accessed 2.6.19).

Persky, J., 2001. Retrospectives: Cost-Benefit Analysis and the Classical Creed. Journal of Economic Perspectives 15, 199–208. https://doi.org/10.1257/jep.15.4.199

Ronen, D., Nauss, R., & Doughty, M., 2003. Upper Mississippi River and Illinois Waterways: How to Reduce Waiting Times of Vessels While Using the Current Infrastructure. URL http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.182.8865&rep=rep1&type=pdf (accessed 2.6.19).

Rosenberger, R.S. & Loomis, J.B., 2003. Benefit Transfer, in: Champ, P.A., Boyle, K.J., Brown, T.C. (Eds.), A Primer on Nonmarket Valuation, The Economics of Non-Market Goods and Resources. Springer Netherlands, Dordrecht, pg. 445–482. https://doi.org/10.1007/978-94-007-0826-6_12

Treasury Board of Canada Secretariat, 2007. Canadian Cost-Benefit Analysis Guide—Regulatory Proposals. URL https://www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf (accessed 2.6.19).

U.S. Army Corps of Engineers (USACE), 1974. Environmental Statement—Locks and Dam No. 26 (Replacement).

U.S. Army Corps of Engineers (USACE), 2000. Planning Guidance Notebook—Engineering Regulation 1105-2-100. URL https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/er_1105-2-100.pdf (accessed 2.6.19).

U.S. Army Corps of Engineers (USACE), 2004. Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study. URL https://www.mvs.usace.army.mil/Portals/54/docs/navigation/SEIS/Library/Other_Documents/Nav_Study_FINAL_Feas_Report_and_EIS_2004.pdf (accessed 2.7.19).

U.S. Army Corps of Engineers (USACE), 2005. Planning in a Collaborative Environment—Engineer Circular 1105-2-409. URL https://planning.erdc.dren.mil/toolbox/library/ECs/ec1105-2-409.pdf (accessed 2.22.19).

U.S. Army Corps of Engineers (USACE), 2008. Final Re-Evaluation of the Recommended Plan: UMR-IWW System Navigation Study. URL https://www.mvr.usace.army.mil/Portals/48/docs/Nav/NESP/NESP%20Economic%20Revaluation%20Interim%20Report%20-%20Final%2020080324.pdf?ver=2016-08-23-124351-107 (accessed 2.8.19).

U.S. Army Corps of Engineers (USACE), 2014. Engineer Technical Letter No. 1100-2-1. URL https://www.publications.usace.army.mil/portals/76/publications/engineertechnicalletters/etl_1100-2-1.pdf (accessed 2.8.19).

U.S. Army Corps of Engineers (USACE), 2016. 2016 Report to Congress—Upper Mississippi River Restoration Program. URL https://umesc.usgs.gov/ltrmp/documents/2016_umrr_rtc_%20final.pdf (accessed 2.14.19).

U.S. Army Corps of Engineers (USACE), 2017. Economic Guidance Memo 18-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2018. URL https://planning.erdc.dren.mil/toolbox/library/EGMs/EGM18-01.pdf (accessed 2.8.19).

U.S. Army Corps of Engineers (USACE), 2018. Public Lock Commodity Report Calendar Years 1999-2017. URL https://publibrary.planusace.us/#/series/Lock%20Performance%20Monitoring%20System%20(LPMS) (accessed 2.25.18).

U.S. Army Corps of Engineers (USACE), 2019a. Backlog of Maintenance - Major Rehabilitation and Major Maintenance [WWW Document]. Rock Island District. URL http://www.mvr.usace.army.mil/About/Offices/Programs-and-Project-Management/District-Projects/Projects/Article/1164618/backlog-of-maintenance-major-rehabilitation-and-major-maintenance-mississippi-r/ (accessed 2.6.19).

U.S. Army Corps of Engineers (USACE), 2019b. National Levee Database, Total Levee Miles for HUC 7 Upper Mississippi Region. URL https://levees.sec.usace.army.mil/#/ (accessed 2.12.19).

U.S. Army Corps of Engineers (USACE), 2019c. Planning Guidance: Engineer Circulars (ECs). URL https://planning.erdc.dren.mil/toolbox/guidance.cfm?Option=Type&BL=None&Type=EC&Sort=Default

U.S. Army Corps of Engineers (USACE), n.d. Navigation and Ecosystem Sustainability Program (NESP). URL https://www.mvr.usace.army.mil/Missions/Navigation/NESP/ (accessed 2.6.19).

Walker, B., 2010. Big Price – Little Benefit: Proposed Locks on the Upper Mississippi and Illinois Rivers are not Economically Viable. Prepared by the Nicollet Island Coalition. URL http://www2.econ.iastate.edu/classes/crp274/swenson/URP290/readings/bigcostlittlebenefitUMRIWW%20critieque%202010.pdf (accessed 2.6.19).

Water Resources Council (WRC), 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.

Water Resources Development Act of 2007, Pub. L. No. 110-114, 121 Stat. 1284. URL https://www.congress.gov/110/plaws/publ114/PLAW-110publ114.pdf (accessed 2.12.19).

EARTH ECONOMICS

Earth Economics is a leader in ecological economics and has provided innovative analysis and recommendations to governments, tribes, organizations, private firms, and communities around the world.

eartheconomics.org | info@eartheconomics.org